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I.—*On the occasional Inversion of the Temperature Relations between the Hills and Plains of Northern India.*—*By* John Eliot, M. A., Meteorological Reporter to the Government of India.

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One of the more important features of the meteorology of the month of January 1889 in Northern India was the remarkable variations of the temperature relations between the hills and plains of Northern India and more especially of Upper India. Under normal conditions of decrease of temperature vertically the temperature at the Punjab hill stations should be 15° to 20° lower than at the adjacent plain stations. The relation is sometimes reversed in the cold weather and the night temperatures are found to be several degrees higher at the hill stations than in the Punjab plains. Such variations or inversions of the ordinary temperature relations are of occasional occurrence in all mountain and adjacent valley districts. They have been observed in previous years in Northern India, but were larger and more prominent in Northern India in January 1889 than has been the case for many years.* The present hence appears to be a favourable period for discussing the

* Similar large and prolonged inversions of temperature occurred in the years 1879, 1880, and 1881 in Upper India.

facts and causes of these occasional inversions of temperature in Northern India.

Before commencing with the subject proper of the paper it is desirable to give a summary of what is known generally of these occasional inversions of the ordinary vertical temperature relations.

Ferrel states it is probable the diurnal temperature oscillations of the upper strata of the atmosphere in the open air away from the influence of contact with the Earth's surface are extremely small. The effect of the Earth's temperature on that of the air above is not so great as it is below, so that this causes the amplitudes in the oscillations of the air temperature near the Earth's surface, though less than those of the Earth's surface, to be greater than those of the air above. The effect of this, it is readily seen, is to cause the temperatures in winter and during the night to approximate more nearly to the temperatures above, and hence to diminish the rate of decrease of temperature with increase of altitude at these times. But during the summer and the warmest part of the day, the effect is the reverse ; it causes the temperatures below to differ still more from the temperatures above, and hence to increase the rate of diminution of temperature with increase of altitude. In the diurnal oscillations the rate near the surface at night from the effect of nocturnal cooling is reversed for some distance above the Earth's surface, the temperature being greater above than at the surface. As the Earth cools, the air in contact also cools when the air is calm, until the surface and likewise the lower air strata are cooled very low and the law of decrease of temperature is reversed. It is different during the day. The increase of the temperature of the Earth's surface, and of the lower strata in contact, brings about a state of unstable equilibrium from which at once arises a vertical interchange of air, by means of ascending and descending currents, which tend to equalize, in some measure, the temperatures above and below, so that, although the Earth's surface may be heated to a much higher temperature than the air immediately above, the decrease of temperature with increase of altitude never becomes very much greater than that of about 1° C. for 100 meters, corresponding to the initial state of unstable equilibrium. The effect of the heat of the Earth's surface cannot be confined to the lower strata merely, as that of the cooling of the surface is, but, as soon as the first stratum in contact with the Earth is heated, the effect is carried to those above.

Sprüng also refers in his meteorology to the same subject and states that the inversion of the ordinary temperature relations takes place occasionally, and usually during periods of very high pressure, and when the amount of cloud and humidity is abnormally small. The cause of the increased temperature at a higher elevation is ascribed to compression of the air.

The following extract from an article on Climate in the *Encyclopædia Britannica* (written by A. Buchan, Esq.), I believe, fairly represents the opinion of English meteorologists on this subject:—

"These results which only affect the mean daily temperature in different seasons, and which are due exclusively to differences of absolute height, though of the greatest possible practical importance, yet leave untouched a whole field of climatological research—a field embracing the mean temperature of different hours of the day at different heights, for an explanation of which we must look to the physical configuration of the earth's surface and to the nature of that surface, whether rock, sand, black soil, or covered with vegetation.

"Under this head by far the most important class of conditions are those which result in extraordinary modifications, amounting frequently to subversions of the law of the decrease of temperature with the height. This will perhaps be best explained by supposing an extent of country diversified by plains, valleys, hills and table-lands to be under atmospheric conditions favourable to rapid cooling by nocturnal radiation. Each part being under the same meteorological conditions, it is evident that terrestrial radiation will proceed over all at the same rate, but the effects of radiation will be felt in different degrees and intensities in different places. As the air in contact with the declivities of hills and rising grounds becomes cooled by contact with the cooled surface, it acquires greater density and consequently flows down the slopes and accumulates on the low-lying ground at their base. It follows, therefore, that places on rising ground are never exposed to the full intensity of frosts at night; and the higher they are situated relatively to the immediately surrounding district the less are they exposed, since their relative elevation provides a ready escape downwards for the cold air almost as speedily as it is produced. On the other hand, valleys surrounded by hills and high grounds not only retain their own cold of radiation, but also serve as reservoirs for the cold heavy air which pours down upon them from the neighbouring heights. Hence mist is frequently formed in low situations whilst adjoining eminences are clear. Along low-lying situations in the valleys of the Tweed and other rivers of Great Britain, laurels, araucarias, and other trees and shrubs were destroyed during the great frost of Christmas 1860, whereas the same species growing on relatively higher grounds escaped, thus shewing by incontestible proof the great and rapid increase of temperature with height at places rising above the lower parts of the valleys.

"This highly interesting subject has been admirably elucidated by the numerous meteorological stations of Switzerland. It is there observed in calm weather in winter, when the ground becomes colder than the air above it, that systems of descending currents of air set in over the whole face of the country. The direction and force of these descending currents follow the irregularities of the surface and, like currents of water, they tend to converge and unite in the valleys and gorges, down which they flow like rivers in their beds. Since the place of these air-currents must be taken by others, it follows that on such occasions the temperature of the tops of mountains and high grounds is relatively high, because the counter-currents come from a great height and are therefore warmer. Swiss villages are generally built on eminences rising out of the sides of the mountains with ravines on both sides. They are thus admirably protected from the extremes of cold in winter, because the descending cold air-currents are diverted aside into the ravines and the counter-currents are constantly supplying warmer air from the higher regions of the atmosphere.

"Though the space filled by the down-flowing current of cold air in the bottom of a valley is of greater extent than the bed of a river, it is yet only a difference of degree, the space being in all cases limited and well defined, so that in rising above it in ascending the slope the increased warmth is readily felt, and, as we have seen, in extreme frosts the destruction to trees and shrubs is seen rapidly to diminish. The gradual narrowing of a valley tends to a more rapid lowering of the temperature for the obvious reason that the valley thereby resembles a basin almost closed, being thus a receptacle for the cold air-currents which descend from all sides. The bitterly cold furious gusts of wind which are often encountered in mountainous regions during night are simply the outrush of cold air from such basins."

The most important recent contribution to the subject is a memoir on "Mountain Meteorology" by Professor William Morris Davis, Harvard College, Cambridge, U. S., in which he gives a summary of the facts up to date. In this he points out that examples of inversion of temperature relations are by no means rare in mountain districts in Europe and America, and that they are most common in winter. He quotes a monograph of Professor Hann's which states that the inversion is best shewn in hill-enclosed valleys where the air stagnates and is not replaced by air from above. Such inversions, it is there pointed out, are most frequent during the passage of areas of high pressure or the prevalence of anti-cyclonic conditions. The unusual warmth in the hill regions is shewn to be an effect of the compression of the descending air, whilst the cold in the valleys and low ground is due to other causes, and takes place in spite of the descent of air into it. A remarkable example in Europe of the inversion due to the prevalence of anti-cyclonic conditions occurred in December 1879 and was the subject of numerous investigations. Hann, in his paper on Die Temperatur Verhältnisse des Decembers 1879, investigated the matter very thoroughly. He made in that paper a comparison between the temperature of Klagenfurth (in the valley) and Hochober (at an elevation of 5215 ft. above Klagenfurth), and states that from December 6th to 18th it was continually warmer on the mountain than in the valley. The mean difference of the 7 A. M. temperatures for these thirteen days was 23·4° in favour of the mountain, at 2 P. M. 21·2°, and at 9 P. M. 19·6° F. Other examples are given in the same memoir of the abnormal vertical temperature conditions which occasionally obtain in Europe and America. Buchan, in a paper published in the Journal of the Scottish Meteorological Society, states that on the 31st December 1883 the temperature at the top of Ben Nevis was 4·5° higher than at Fort William. In this case too pressure was abnormally high. Woeikoff, the Director of the Russian Meteorological Department, on the strength of certain evidence, believes there is a persistent inversion of temperature during the winter in Siberia. Inversion of temperature is also said to be of common occurrence on Mount Washington (in Massachusetts). It is also occasionally shewn by the Pikes' Peak Observations. That mountain has an elevation of 14134 feet and is 8,840 feet higher than Denver. Professor Loomis gives 39 examples of higher temperature at the top of Pikes' Peak than at Denver from four years' observations. In the most extreme cases the differences of temperature amounted to 15° and 16°. It may be noted that these inversions all occurred during the winter.

It is not necessary to quote from the earlier meteorological works of Herschel, Buchan, &c., as they only recognize the occasional occurrence of lower temperature at night in valleys than on the adjacent hills, and ascribe the effect chiefly to the flow of cold air down the sides of the hills.

Recent meteorological writings in some cases continue to ascribe the cooling almost entirely to the descent of the air from the mountain sides into the valleys, and state that the inversion of the vertical temperature relations is of comparatively frequent occurrence in mountanous districts. The facts about to be given, however, appear to indicate the probability that these inverse relations which are exhibited by the mountain observations are due to general conditions that prevail in plains as well as in mountain districts, and hence that similar relations may obtain much more generally and widely than is usually supposed. No distinct statement, however, occurs to this effect, so far as I am aware, and the evidence of inversion of the vertical temperature relations is, in the absence of suitable balloon observations, confined to differences between mountain stations and the neighbouring valley or other low-lying stations. They are hence assumed to be phenomena restricted to hills and the neighbouring confined valleys and hence of limited extent. The explanation generally given, whilst making the inversion a phenomenon of terrestrial radiation, attaches much weight to the flow of cool air down the mountain sides into the valleys, and hence suggests that it is peculiar to mountain districts.

The present paper will, I believe, prove that inversion may occur over very large plain areas, and that it has, in some cases at least, little or nothing whatever to do with air motion between hills and valleys. It will also shew that the vertical temperature relations during the cold weather in Northern India are much more variable and complicated than they have been hitherto supposed to be, and that the descensional motion which accompanies cooling of the air during the night in fine clear weather is almost entirely one of slow compression, and is not the opposite of the ascensional and convective movement which takes place largely during the day, or, in Professor Ferrel's suggestive words, "the effect of the heating of the earth's surface is not confined to the lower strata merely, as that of the cooling of the surface is, but as soon as the first stratum in contact with the earth is heated, the effect is carried to these above." The principle is, I believe, of great importance generally, and more especially in India, in connection with the production of the dry winds of the Gangetic plain during the hot weather months of March, April, and May.

The paper consists of three parts ;—1st, a statement of the normal meteorological temperature conditions of the plain and hill districts of Upper India in the month of January and of certain meteorological conditions and actions upon which temperature mainly depends ; 2nd, a statement of the more striking abnormal temperature relations of the month of January 1889 and of the cold weather period generally in Upper India ; and 3rd, a discussion of the causes which produce these unusual temperature conditions and variations.

It may be premised that one or two of the actual observations quoted for the month of January 1889 appear to me to be somewhat doubtful. I have, however, thought it best to include them, as it is on the whole more probable that they are exaggerated examples of the peculiar temperature relations about to be discussed than that they represent instrumental or observational errors.

The following table gives the average maximum temperatures of the month of January of certain selected pairs of stations in Upper India, each pair consisting of a hill station and the nearest plain station at which there is an observatory :—

Names of pairs of stations.	Difference of elevation.	Distance in miles.	Mean maximum temperature for January.		Difference of maximum temperature of the plain and hill stations.	Average rate of change of temperature vertically at the hottest period of the day per 1000 feet.
			Hill station.	Plain station.		
Quetta / Jacobabad	5300	163	51·6°	73·3°	21·7°	4·1°
Murree / Rawalpindi	4700	30	47·8°	63·3°	15·5°	3·3°
Simla / Ludhiana	6200	80	51·2°	67·6°	16·4°	2·7°
Chakrata / Roorkee	6200	58	50·1°	69·4°	19·3°	3·1°
Ranikhet / Bareilly	5500	90	54·0°	70·1°	16·1°	2 9°
Dhubri / Darjeeling	7300	116	44·3°	73·4°	29·1°	4·0°
Deesa / Mount Abu	3500	40	67·1°	82·2°	15·1°	4 3°
Pachmarhi / Hoshangabad	2500	48	70·6°	80·1°	9·5°	3·8°

A full description of these observatories and of the more important local peculiarities of exposure will be found in Mr. Blanford's Report on the Meteorology of India for 1885. It will suffice here to point out that both Ranikhet and Simla are situated at some distance within the first line of hills, whereas Murree and Chakrata are practically on the crest of the first line of elevations overlooking the plains. Assuming these as more typical of the relations between hills and plains, the preceding data shew that in Upper India the temperature near the hills decreases vertically with elevation at the hottest time of the day in the month of January very nearly 3° in 1000 feet up to a height of 7000 feet at least. The remarkably low day temperature at Darjeeling during this period as shewn by the table appears to be due to the following causes, of which the first is probably the most influential.

1*st.*—The great humidity and large amount of fog at that station (as in the Eastern Himalayan districts generally) in January, in which respects it contrasts strikingly with the hill stations of Upper India, where the air is, except in stormy weather, very dry and clear.

2*nd.*—The contiguity of the immense snow mass of Kanchinjunga and neighbouring mountains, which include some of the highest peaks in the Himalayas. This area embraces an enormous extent of snow covered ground, the southern edge of which (in summer) is at a distance as the crow flies of not more than 30 or 35 miles from Darjeeling. The first line of snows is at a distance of at least 45 or 50 miles from Simla and Murree and at a distance of about 40 miles from Chakrata. The neighbouring areas of perpetual snow are of greater elevation and of considerably less extent in the case of all these stations than of Darjeeling and hence exercise a much smaller influence.

As the meteorological conditions of Darjeeling are thus essentially different from those of the hill stations of Upper India, it will be excluded from the final discussion, although data for it are given in the tables for the preliminary comparisons.

The following table gives the average minimum temperature data for the same pair of stations for the month of January.

Names of pairs of stations.	Difference of elevation.	Distance in miles.	Mean minimum temperature for January.		Difference of minimum temperature of plain and hill stations.	Average rate of decrease of temperature at the coldest period of the night per 1000 ft.
			Hill station.	Plain station.		
Quetta ... Jacobabad ...	5300	163	29·2°	42·8°	13·6°	2·6°
Murree ... Rawalpindi ...	4700	30	35·5°	37·9°	2·4°	0·5°
Simla ... Ludhiana ...	6200	80	36·4°	43·5°	7·1°	1·1°
Chakrata ... Roorkee ...	6200	58	35·7°	44·2°	8·5°	1·4°
Ranikhet ... Bareilly ...	5500	90	39·5°	45·9°	6·4°	1·2°
Dhubri ... Darjeeling ...	7300	116	34·6°	53·5°	18·9°	2·6°
Deesa ... Mount Abu ...	3500	40	50·9°	51·1°	0·2°	0
Pachmarhi ... Hoshangabad ...	2500	48	47·2°	52·5°	5·3°	2·1°

This table shews that at all these stations the average difference of temperature at night is much smaller than by day. The rate of difference is greatest in the cases of Quetta and Jacobabad, Pachmarhi, and Hoshangabad, and Darjeeling and Dhubri, for which it averages about 2° or less than half of the rate of difference for the maximum temperature. The result for Deesa and Mount Abu is so anomalous as to point to peculiar local conditions, the nature of which have, however, not yet been determined.* In the case of the pairs of stations in Upper India the average rate of change of temperature with

* I have recently (January 1890) visited these two stations: the temperature observations are carefully recorded, and are taken under the same conditions of ex-

elevation at night in January varies from 0·5° for Murree and Rawalpindi to 1·4° for Chakrata and Roorkee, and averages 1°, that is, little more than one third of the day rate of decrease of temperature vertically.

These two tables may hence be summarized as follows :—

(*a*). The rate of decrease of temperature with elevation at the time of maximum day temperature in the month of January averages 3° per 1,000 feet in the Western Himalayas and 4° per 1,000 feet in the Eastern Himalayas up to 7,000 feet and in the Aravalli and Vindhya Hills and perhaps also in Beluchistan.

(*b*). The rate of decrease of temperature with elevation at night or at the time of minimum temperature averages 1° per 1,000 feet in the Western Himalayas, 2° per 1,000 feet in the Eastern Himalayas and Vindhyas, and 2½° per 1,000 feet in Beluchistan.

An interesting point in connection with the night temperature in the plains of Upper India is shewn by the data of the following table. The first column gives the average minimum temperature of the month of January at stations nearest to the hills and the second that of stations at a greater distance than those of the first column.

Plain stations near hills.	Mean minimum temperature for January. (A.	Plain stations at considerable distance from hills.	Mean minimum temperature for January. (B.)	Difference between mean temperature of the two stations for each pair. A—B.	Horizontal distance between pair of stations.
Rawalpindi ...	37·9°	Peshawar	39·1°	— 1·2°	100 miles
Sialkot ...	42·9°	Lahore	42·4°	0·5°	75 „
Ludhiana ...	43·5°	Sirsa	42·4°	1·1°	100 „
Roorkee ...	44·2°	Meerut	44·4°	— 0·2°	60 „
		Delhi			90 „
Bareilly ...	45·9°	Agra			120 „
		Lucknow	45·9°	0°	125 „
Gorakhpur ...	48·6°	Allahabad	47·5°	1·1°	125 „
		Benares	47·9°	0·7°	100 „
Dhubri ...	53·5°	Berhampore	53·2°	0·3°	150 „

The geographical relations between Rawalpindi and Peshawar are quite different from those of the other pairs of stations, which are all situated in the great plain of Northern India stretching along the foot of the Himalayas from the North Punjab to East Bengal.

posure as at other stations in India. Several series of hourly observations of temperature during the night have been recently taken, and, as they confirm the conclusions of the present paper, I hope to discuss them in a brief paper to be submitted to the Society shortly.

The differences here are small and to some extent undoubtedly depend upon the peculiarities of position of the observatories at the observing stations. Their general uniformity, however, appears to indicate clearly that the lowest minimum temperatures in January in the great Northern or Gangetic plain of India are not found at and near the foot of the hills, but in the midst of the great plain at a distance of 100 to 200 miles from the Himalayas, or, as it might be more fully expressed, the axis of minimum or lowest night temperature in Northern India in the month of January runs nearly parallel to the Himalaya mountains at a distance from their southern base varying from 100 to 200 miles. This fact seems to be of great importance as it shews that, whatever the rapid cooling in these plains may be due to, it cannot be ascribed to the cause usually assigned for the greater cold in valleys than in hill sides, *viz.*, the sinking of air cooled by contact with the sides of the hills into the valleys. For it is not possible that the cooled air sinking down with a motion which is imperceptible to the anemometer or senses should produce the greatest effects at distance of one or two hundred miles from the foot of the hills and where the temperature is higher by day, as is shewn by the following table:—

Plain stations near hills.	Mean maximim temperature January. (A.)	Plain stations at considerable distance from hills.	Mean maximum temperature January. (B.)	Difference between mean temperature for the two stations of each pair. (B—A.)	Horizontal distance between stations.
Rawalpindi ...	63·3°	Peshawar	64 0°	0 7°	100 miles
Sialkot ...	66 7°	Lahore	67 6°	0·9°	75 "
Ludhiana ...	67·6°	Sirsa	70·8°	3·2°	100 "
Roorkee ...	69 4°	Meerut	70·1°	0·7°	60 "
Bareilly ...	70·1°	Delhi	71·0°	0·9°	90 "
		Agra	73·4°	3·3°	120 "
		Lucknow	73·8°	3 7°	125 "
Gorakhpur ...	73·4°	Allahabad	73·6°	0·2°	125 "
		Benares	74·7°	1·3°	100 "
Dhubri ...	73·4°	Berhampore	78·2°	4·8°	150 "

The following table gives mean daily temperature (*i. e.*, means of the maximum and minimum temperatures) data of the month of January for the same pairs of stations:—

Pairs of stations.	Difference of Elevation.	Mean daily temperature January. Hill station. (A.)	Plain station. (B.)	Difference. B.—A.	Rate of decrease per 1000 ft.
Quetta ... / Jacobabad ...	5300	40·4°	58·0°	17·6°	3·3°
Murree ... / Rawalpindi ...	4700	41·7°	50·6°	8·9°	1·9°
Simla ... / Ludhiana ...	6200	43·8°	55·6°	11·8°	1·9°
Chakrata ... / Roorkee ...	6200	42·8°	56 8°	14·0°	2·3°
Ranikhet ... / Bareilly ...	5500	46·7°	58·0°	11·3°	2·1°
Dhubri ... / Darjeeling ...	7300	39·5°	63·5°	24·0°	3·3°
Deesa ... / Mount Abu ...	3500	59·0°	66·7°	7·7°	2·2°
Pachmarhi ... / Hoshangabad ...	2500	58·9°	66·3°	7·4°	3·0°

The data of this table are not of much importance in connection with the present discussion. They shew that the average decrease of temperature with elevation (as determined from day and night observations) varies from 1·9° per 1000 feet in the North-West Himalayas to 3·3° per 1000 feet in Beluchistan and Sind, where the general climatic conditions at that time are apparently very similar to those of the Punjab.

The following table gives the average daily range of temperature at the plain and hill stations of each pair of stations.

Pairs of stations.	Average daily range of temperature for January. Hill station. (A.)	Plain station. (B.)	Ratio of daily range at plain station to that at hill station. (B.)/(A.)
Quetta ... ... / Jacobabad	22.4°	30·5°	1·4°
Murree ... ... / Rawalpindi	12·3°	25·4°	2·1°
Simla ... ... / Ludhiana	14·8°	24.1°	1·6°
Chakrata ... . / Roorkee	14·4°	25·2°	1·7°
Ranikhet ... ... / Bareilly	14 5°	24·2°	1·7°
Darjeeling ... ... / Dhubri	9·7°	19·9°	2·0°
Mount Abu ... ... / Deesa	16·2°	31·1°	1·9°
Pachmarhi ... ... / Hoshangabad	23·4°	27·6°	1·2°

This shews that in Upper India the average daily range of temperature in January is very nearly twice as great in the plains as at the adjacent hill stations at elevations of 6000 to 7000 feet. The ratio is even greater in the Eastern Himalayas, the daily range of temperature probably varying from $2\frac{1}{2}$ to 3 times as much in Assam and North Bengal as it is in the adjacent Himalayas at an elevation of 7000 feet. In the hills of Upper India this diminished range of temperature cannot be ascribed to any deficiency of radiating power, either of the sun or of the earth at this period of the year, for the air is much clearer (free from dust, smoke, etc.) and drier in the hills than the plains in Upper India, and, as shewn in the following tables, solar heat is absorbed more largely by day and terrestrial heat given out more rapidly by night in the hills than in the adjacent plain districts. The only measure for the radiating power in either case that we at present possess is the average daily difference between the readings of the solar radiation thermometer and maximum thermometer in the one case and between the readings of the grass radiation thermometer and minimum thermometer in the other. The following two tables give these differences for the pair of stations selected.

Names of pairs of stations.	Average difference between readings of solar radiation and maximum thermometer in shade. January.		Ratio of difference for hill station to that for plain station.
	Hill stations. A.	Plain station. B.	$\frac{A.}{B.}$
Quetta ... ... Jacobabad	62·9°	59·9°	1·1°
Murree ... ... Rawalpindi	60·4°	50·6°	1·2°
Simla ... ... Ludhiana	62·7°	51·5°	1·2°
Chakrata ... ... Roorkee	67·0°	54·3°	1·2°
Ranikhet ... ... Bareilly	60·7°	48·0°	1·3°
Darjeeling ... ... Dhubri	54·4°	50·1°	1·1°
Mount Abu ... ... Deesa	62·2°	53·4°	1·2°
Pachmarhi ... ... Hoshangabad	61·8°	55·8°	1·1°

This table establishes conclusively that the average direct heating power of the sun is greater at the hill stations in January than at the corresponding plain stations. And, if it might be assumed that the relative intensity in the two cases is, roughly speaking, proportional to the ratios given in the preceding table, the heating power of the sun at an elevation of 7000 feet in the Himalayas is on the average about one-fifth greater than at the level of the adjacent plains, or, in consequence of the absorbing action of the lower strata, the sun is one-sixth less powerful in heating the earth's surface at the level of the plains than it is at that of the hill stations of the Himalayas.

The following table gives similar data for nocturnal radiation from the Earth's surface:—

Names of pairs of stations.	Average difference between grass radiation thermometer readings and those of minimum in shade thermometer for January.		Ratio of difference for hill station to that of corresponding plain station $\frac{A.}{B.}$
	Hill station. A.	Plain station. B.	
Quetta ... ... Jacobabad	10·4°	10·1°	1·0°
Murree ... ... Rawalpindi	11·4°	7·3°	1·6°
Simla ... ... Ludhiana	12·2°	9·8°	1·3°
Chakrata ... ... Roorkee	9·5°	7·2°	1·3°
Ranikhet ... ... Bareilly	13·0°	8·3°	1·6°
Darjeeling ... ... Dhubri	10·3°	6·9°	1·5°
Mount Abu ... ... Deesa	17·1°	9·1°	1·9°
Pachmarhi ... ... Hoshangabad	12·0°	8·5°	1·4°

These figures show that nocturnal radiation goes on much more rapidly at the hill stations than at the adjacent plain stations, and that the ratios as measured by the differences given in the preceding table are much greater than the ratios in the corresponding tables for solar radiation. Taking the average of all the stations as a rough approximation, they appear to indicate that nocturnal radiation goes on upwards of 50 per cent. more rapidly at the hill stations than at the adjacent plain stations.

This result is undoubtedly in part due to the greater length of the night (or period of effective terrestrial radiation) than of the day in the month of January in Northern India, and perhaps also to the greater clearness and homogeneity of the atmosphere arising from the stillness of the air and absence of wind at night as compared with the day. It will, however, be presently seen it is probable that the mean monthly minimum temperature at the hill stations represent an average of conditions different from that at the plain stations and hence the figures given above are almost certainly of little value for the comparison of nocturnal radiation in the plains and hills of Northern India. It is, however, evident that the figures as a whole support the inferences based on the known laws of radiation from cooling bodies. It is certain therefore that in clear weather in January, if there were no other action than mere radiation and heating and cooling of the adjacent air by contact with the Earth's surface, the Earth's surface and adjacent air would be heated to a greater extent by day and cooled to a larger amount at night at the hill stations than at the plain stations and hence the daily range of temperature might be expected on this account alone to be considerably greater (probably from 10° to 20°) at the hill stations than at the plains.

The following table gives the average cloud amount during the month at the selected stations.

Names of pairs of stations.	Mean proportion of cloud in January. Hill station. A.	Mean proportion of cloud in January. Plain station. B.	Ratio of cloud proportion of hill station to plain station. $\frac{A.}{B.}$
Quetta ... ... / Jacobabad	4·4	2·6	1·7
Murree ... ... / Rawalpindi	5·8	4·4	1·3
Simla ... ... / Ludhiana	5·6	3·9	1·4
Chakrata ... ... / Roorkee	4·8	3·4	1·4
Ranikhet ... ... / Bareilly	4·1	3·0	1·4
Darjeeling ... ... / Dhubri	5·5	1·7	3·2
Mount Abu ... ... / Deesa	2·6	2·2	1·2
Pachmarhi ... ... / Jubbulpore	2·3	2·2	1·0

The following table gives the average humidity of the month of January at the same pairs of stations.

Names of pairs of stations.	Mean relative humidity in January. Hill station. A.	Plain station. B.	Ratio of average humidity of hill station to that of plain station. $\frac{A.}{B.}$
Quetta ... ... / Jacobabad	67	47	1·4
Murree ... . / Rawalpindi	59	73	0·8
Simla ... ... / Ludhiana	61	68	0·9
Chakrata ... ... / Roorkee	63	65	1·0
Ranikhet ... ... / Bareilly	63	67	0·9
Darjeeling ... ... / Dhubri	79	77	1·0
Mount Abu ... ... / Deesa	40	38	1·0
Pachmarhi ... ... / Jubbulpore	54	60	1·1

These tables show that while the amount of cloud is considerably greater at the hill-stations that at the plain stations in Upper India, the air is actually on the average drier or less humid in the former case. As these results are based on day observations chiefly, it is probable if night observations of equal weight were included the difference would be even more marked.

The following is a brief general summary of the mean temperature conditions at the level of the hill stations in the Himalayas and on the adjacent plains.

(1.) The rate of decrease with elevation of the average daily temperature of the month of January is very approximately $2\frac{1}{8}^\circ$ per 1,000 feet or more exactly 1° per 470 feet. The rate of decrease is, however, very irregular, varying not only from day to day but also from hour to hour during the day. The rate of decrease of the average minimum or night temperature with elevation in Upper India is only about $1\frac{1}{4}^\circ$ per 1,000 feet and of the average maximum temperature is 3° per 1,000 feet.

(2.) The daily range of temperature is much less at the hill stations than in the adjacent plain districts and is little more than half that at the adjacent plain stations.

It also follows from the previous remarks that any explanation of the smaller average difference of the minimum temperature at the hills and at the adjacent plain stations (or of the small night vertical range of temperature compared with the day) must recognize:—

(*a.*) That the air is on the average less humid at the hills than at the adjacent plain stations in Upper India.

(*b.*) That there is on the average more cloud at the hill stations.

(*c.*) That the intensity of solar radiation is considerably greater at the hill stations, probably at least 20 per cent. greater.

(*d.*) And that the intensity of radiation from the earth's surface at night is very considerably greater at the hills than the adjacent plains.

We now proceed to give data for the same pairs of stations for January 1889.

The following tables give the comparative temperature data of eight hill stations in Northern India and of the eight nearest plain stations at which there are observations for that month.

The first table gives the maximum temperature of each day of the month of January 1889 and the variation from the normal. The variations are obtained from the daily means of the past eleven years (1878-88) smoothed so as to give a fairly regular series. The positive sign affixed to a number in this table indicates that the actual temperature was above the normal and a minus sign that it was below it.

The second table gives similar date for the minimum temperature of the same 16 stations for the same period.

The third table gives the daily difference of the maximum temperatures for each of eight pairs of stations consisting of a hill station and adjacent plain station. Iu every case the maximum temperature at the plain stations exceeds that at the neighbouring hill station.

The fourth table gives the difference between the minimum temperature registered at each of the eight selected hill stations and the neighbouring plain stations. In the majority of cases the minimum temperatures at the plain stations exceed those at the plain stations in which case no sign is prefixed to the number. In a few cases the latter temperatures are the greater and this is indicated by the minus sign prefixed to the number.

Table I. giving the maximum temperature of the 24 hours preceding 8 A. M. at 16 stations for the month of January, 1889 and the variations from the normal day by day.

January.	Quetta. Actual.	Quetta. Variation.	Jacobabad. Actual.	Jacobabad. Variation.	Murree. Actual.	Murree. Variation.	Rawalpindi. Actual.	Rawalpindi. Variation.	Simla. Actual.	Simla. Variation.	Ludhiana. Actual.	Ludhiana. Variation.	Mussooree. Actual.	Mussooree. Variation.	Roorkee. Actual.	Roorkee. Variation.	Ranikhet. Actual.	Ranikhet. Variation.	Bareilly. Actual.	Bareilly. Variation.	Darjeeling. Actual.	Darjeeling. Variation.
1	51·6	−2·7	75·4	+1·5	53·2	+2·6	64·1	−0·1	54·5	+1·5	68·2	+0·2	54·0	?	68·8	−1·2	60·7	+4·0	72·2	+1·6	4·8	−0·4
2	60·5	+6·7	73·4	−0·2	57·1	+6·3	69·1	+4·5	56·7	+4·4	69·7	+1 8	54·0	?	70·8	+0·6	62·7	+6·8	73·7	+3·0	43·6	−0·9
3	60·5	+7·3	74·4	+1·3	59·1	+8·5	70·5	+6·0	61·7	+9·4	75·2	+7·1	60·0	?	70·8	+0·7	66·1	+10·5	71·2	+0·5	46·8	+2·3
4	56·6	+4·0	76·9	+4·2	58·6	+9·2	68·6	+4·5	66·9	+14·7	77·7	+9·5	63·5	?	72·3	+2·3	71·1	+15·7	77·2	+6·7	50·9	+6·8
5	50·6	−2·0	76·9	+4·5	49·2	−0·5	69·1	+4·9	57·3	+4·8	73·2	+5·1	61·0	?	72·8	+2·8	66·1	+10·7	75·2	+4·7	52·3	+7·9
6	56·1	+3 4	77·4	+5·0	52·7	+2·2	69·1	+4·5	50·1	−3·1	73·2	+5·3	53·0	?	71·8	+2·1	62·7	+7·2	75·2	+4·9	47·0	+1·7
7	56·6	+3·0	75·4	+2·8	56·6	+5·8	70·0	+5·4	54·1	+0·1	75·7	+8·0	52·0	?	75·8	+6·1	57·8	+2·0	76·2	+6·2	45·7	−0·6
8	57·1	+3·6	78·4	+5·5	54·7	+3·8	66·6	+2·2	59·7	+5·2	72·7	+5·2	56·0	?	73·3	+3·4	63·2	+7·1	75·2	+5·1	46·4	−0·3
9	60·5	+7·3	78·9	+5·7	58·6	+7·7	72·0	+7 7	58·2	+3·7	72·2	+5·1	60·0	?	71·8	+2·3	62·2	+6·2	72·7	+2·7	46·6	−6·6
10	59·1	+6·5	72·9	−0·5	55·2	+4·4	64·6	+0·4	57·7	+4·0	73·2	+6·2	57·5	?	70·3	+0·8	62·2	+6·1	75·2	+5·2	44·8	−2·7
11	49·6	−1·9	77·1	+4·6	42·7	−7·1	70·5	+6·2	48·5	−4·3	69·2	+2·1	52·0	?	70 3	+0·8	58·2	+2·6	75·2	+5·6	49·1	+2·2
22	46·5	−4·1	77·4	+4·2	43·7	−5·2	64·1	+0·2	50·8	−1·0	72·2	+5·1	52·0	?	76·8	+7·2	58·2	+3·0	77·7	+8·1	45·8	−0·6
13	42 0	−8·3	70·4	−2·6	42·2	−6·2	61·6	−2·1	50·7	−0·3	66·7	−0·4	58·5	?	71·8	+2·1	55·3	+0·6	76·2	+6·7	?	?
14	42·5	−8·2	72 4	−0·5	42·7	−5·5	60·1	−3·6	40·5	−10·0	67·7	+0·8	52·0	?	70·8	+1·1	55·3	+1·0	76·2	+6·6	50·1	+5·2
15	41·5	−9·4	72·4	−0·7	40·7	−6·9	62·6	−0·8	41·8	−8·6	70·7	+3·6	50·0	?	74·3	+5·0	54·3	+1·0	75·2	+5·9	50·3	+6·1
16	41·5	−10·2	67·4	−5·8	42·7	−5·1	61·1	−2·0	44·3	−6·2	70·2	+3·0	54·5	?	70·3	+1·0	49·3	−4·1	71·2	+1·6	49·5	5·1
17	33·4	−19·2	69·9	−3·1	32·1	−16·0	55 2	−8·1	44·3	−6·6	71·2	+4·0	53·5	?	75·3	+6·0	47·4	−6·3	66·1	−3·6	?	?
18	31·4	−21 6	70·9	−2·5	42·7	−5·4	61 1	−2·2	49·6	−1·5	72·7	+5·2	50·0	?	76·3	+7·6	57·3	+4·6	76·7	+7·1	47·5	+3·2
19	32·4	−20·7	68·9	−5·0	40·1	−7·7	58·6	−4·8	50·1	−1·0	71·2	+3·1	50·0	?	74·8	+6·0	51·3	−1·6	76·2	+6·8	51·3	+7·2
20	53·6	+0·6	69·9	−4·3	48·7	+0·9	65·1	+1·6	51·5	+0·3	67·2	−1·0	50·5	?	73·8	+4·6	57·3	+4·0	77·2	+7·6	51·1	+6·4
21	56·1	+3·2	71·4	−3·0	64·1	+16·8	69·1	+5·9	59·5	+8·5	74·2	+6·4	51·5	?	73·8	+5·1	64·1	+11·2	74·2	+4·7	54·1	+9·3
22	53·6	+0·9	74·4	−0·3	55·7	+9·0	66·1	+3·3	62·3	+11·6	73·7	+5·6	60·5	?	75·3	+6·6	66·1	+13·7	73·2	+3·6	45·2	+0·7
23	45·5	−7·1	74·4	−0·1	37·6	−8·7	61·1	+1·1	50·3	−0·3	66·2	−1·6	50·5	?	73·8	+6·7	64·1	+10·6	76·2	+6·2	46·0	+1·9
24	46·0	−6·0	76·9	+3·0	42·2	−3·5	67·1	+5·2	42·2	−8·4	60·7	−7·0	46·0	?	64·8	−4·4	57·3	+3·8	61·1	−9·3	48·0	+4·0
25	51·6	+0·1	73 4	0	47·7	+1·8	67·6	+5·4	43·1	−7·1	66·2	−1·6	43·0	?	65·8	−3·2	49·3	−3·9	62·6	−8·0	43·3	−0·4
26	49·6	−1·2	72·9	0	49·7	+4·2	65·1	+3·1	48·5	−1·4	69·2	+1·0	48·0	?	69.8	+0·5	54·3	+1·5	71·2	+0·3	48·1	+4·5
27	43·0	−6·8	76·4	+3 7	46·7	+1·4	63·1	+1 0	44·3	−5·4	66·2	−1·6	48·5	?	64·8	−4·4	53·3	+0·8	72·2	+1·1	47·5	+4·0
28	43·5	−5·5	70·4	−2·2	44·7	−0·3	58·1	−4·4	52·7	+3·1	69·7	+1·8	53·5	?	75·8	+6·4	58·2	+5·9	73·7	+2·7	43·2	−0·2
29	42·5	−6·0	70·4	−2·5	38·6	−6·7	54·2	−8·6	48 1	−1·4	59·7	−8·3	51·0	?	63·8	−5·6	58·2	+6·1	75·2	+4·2	46·0	+3·3
30	40·5	−7·7	66·4	−7·0	36·6	−8·4	52·7	−9·4	43·1	−6·0	63·2	−4·2	42·5	?	61·8	−7·5	58·2	+6·0	69·2	−1·4	50·1	+7·4
31	35·4	−13.2	70·4	−3·4	32·6	−13·1	54·2	−8·2	39·5	−9·3	61·2	−6·3	34·0	?	58·3	−11.1	57·3	+5·3	70·2	−0·2	42·1	0
Mean.	48·1	−3·7	73·4	+0·1	47·4	−0·7	63·9	+0·5	51·1	−0·3	69·7	+2·0	52 4	?	71·0	+1·6	58·7	+4·6	73·2	+3·1	47·5	+2·8

Table I.—Continued.

January.	Dhubri. Actual.	Dhubri. Variation.	Abu. Actual.	Abu. Variation.	Deesa. Actual.	Deesa. Variation.	Pachmarhi. Actual.	Pachmarhi. Variation.	Hoshangabad. Actual.	Hoshangabad. Variation	General character of weather in Upper India.
1	74·3	+1·0	68·1	+0·3	86·2	+3·4	70·9	+1·7	80·7	+2·3	Barometer rising, clear.
2	73·8	+0·8	72·6	+4·7	88·2	+5·2	71·4	+2·5	80·7	+2·6	Do. do. light clouds Punjab.
3	74·3	+1·4	73·1	+5·1	89·2	+6·3	72·3	+3·4	80·2	+2·0	Do. falling, cloudy plains and hills.
4	75·3	+2·3	71·6	+3·8	88·2	+5·5	74·8	+5·7	83·1	+4·5	Do. ,, cloudy Punjab and hills.
5	75·8	+2·7	67·6	−0·5	87·2	+4·4	75·8	+6·3	84·1	+5·1	Do. rising rapidly, skies cloudy.
6	74·3	+1·3	67·1	−1·0	86·2	+3·4	74·8	+4·7	85·1	+5·8	Do. do. skies clear.
7	77·3	+4·4	70·1	+1·9	89·2	+6·3	75·8	+5·4	84·1	+4·7	Do. do. do. do.
8	76·8	+3·8	73·6	+5·2	91·3	+8·6	74·8	+4·2	83·6	+4·0	Do. falling, no cloud.
9	74·3	+1·3	72·1	+4·0	93·3	+10·7	74·8	+3·9	84·6	+5·0	Do. do. light cloud.
10	75·3	+2·1	71·1	+3·6	91·3	+9·3	75·3	+4·2	85·6	+5·8	Do. do. do. do.
11	75·3	+1·9	68·1	+1·1	88·2	+7·1	77·7	+6·8	88·6	+8·8	Do. do. moderate cloud.
12	75·3	+1·6	67·6	+1·0	87·2	+6·4	75·8	+5·1	85·6	+5·8	Do. do. Skies clouded, especially over hills.
13	77·8	+4·2	66·1	−0·3	84·6	+3·6	74·8	+4·2	84·6	+4·9	Do. rising, Snow on hills.
14	75·8	+2·0	62·1	−4·5	82·1	+0·7	72·8	+2·4	81·6	+1·8	Do. do. clear plains, overcast hills.
15	77·3	+3·3	60·6	−6·5	80·1	−2·0	72·3	+2·1	79·7	−0·1	Do. do. do.
16	78·8	+4·7	60·6	−6·9	78·6	−4·0	74·8	+4·7	82·1	+2·4	Do. do. Snow falling on hills.
17	77·8	+3·6	64·1	−3·9	79·6	+3·6	77·7	+7·3	86·6	+6·6	Do. do. Generally clear.
18	78·8	+4·4	67·1	−1·1	83·6	+0·3	77·7	+7·2	87·6	+7·2	Do. falling.
19	78·8	+4·7	66·1	−1·9	80·1	−3·3	76·3	+5·9	87·6	+7·2	Do. rising.
20	79·8	+5·9	64·1	−3·7	77·1	−6·2	75·8	+5·1	86·6	+6·1	Do. falling, clear.
21	77·8	+4·1	70·1	+2·5	86·2	+3·0	77·3	+6·5	83·6	+3·0	Do. do.
22	76·3	+2·8	73·6	+6·0	92·3	+9·4	78·7	+7·9	88·6	+8·1	Do. do. Snow storm Murree and Quetta.
23	77·8	+4·4	71·6	+3·8	89·2	+6·6	79·7	+8·6	91·1	+10·5	Do. do. Snow storm hill stations.
24	78·3	+4·9	63·1	−4·8	83·1	−0·1	78·7	+7·2	88·6	+7·5	Do. rising rapidly. Snow on hills, rain on plains.
25	73·3	−0·1	64·1	−3·1	83·1	+0·5	71·4	−0·2	80·2	−1·1	Do. rising.
26	75·8	+2·3	68·1	+1·7	87·2	+5·3	75·8	+4·4	84·6	+3·1	Do. do. moderate cloud Upper India.
27	76·3	+2·9	70·1	+4·5	89·2	+7·8	75·3	+4·1	88·1	+6·8	Do. falling, moderate cloud.
28	77·8	+4·6	70·6	+5·7	87·7	+6·8	79·7	+8·6	88·1	+7·1	Do. falling rapidly, rain N. Punjab.
29	78·3	+5·3	74·1	+9·6	91·3	+10·9	80·7	+9·6	88·6	+8·0	Do. falling very rapidly, rain & snow hills, overcast N. India.
30	78·8	+5·8	63·1	−1·6	84·6	+4·1	81·7	+10·5	90·6	+9·9	Do. falling Heavy snow storms on hills.
31	65·7	−7·2	57·1	−8·3	78·1	−2·8	75·3	+4·0	85·6	+5·1	Do. rising very rapidly, snow on hills.
Mean.	76·2	+2·8	67·7	+0·5	85·9	+3·6	75·8	+5·3	85·2	+5·2	

Table II. giving the minimum temperature daily during the month of Jannary 1889 at 16 stations and the variations from the normal day by day.

Date.	Quetta.		Jacobabad.		Murree.		Rawalpindi.		Simla.		Ludhiana.		Mussooree.		Roorkee.	
	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variatio n.	Actual.	Variation.	Actual.	Variation.
1	26·8	−0·6	38·6	−2·1	37·7	+0·8	30·9	−3·8	40·3	+3·5	41·0	−0·4	42·0	?	38·9	−3·1
2	31·8	+4·4	40·6	−0·3	45·8	+8·6	37·4	+2·1	45·1	+8·2	41·0	−0·6	41·5	?	38·9	−3·6
3	30·3	+2·1	38·6	−2·3	49·3	+12·6	36·9	+0·8	48·4	+11·6	45·6	+3·6	42·0	?	36·3	−6·5
4	33·8	+5·9	38·6	−2·2	44·8	+8·4	39·4	+3·1	46·1	+9·0	41·5	−0·6	48·5	?	45·1	+2·2
5	23·8	−3·8	41·6	+1·0	34·7	−2·0	38·4	+2·1	40·7	+2·9	49·2	+7·0	44 0	?	47·7	+5·0
6	25·3	−2·5	38·6	−2·4	37·7	+0·2	34·9	−1·5	39·3	+0·9	44·6	+2·5	39·0	?	43·1	+0·5
7	35·8	+7·2	40 1	−1·3	42·7	+5·2	37·9	+1·1	41·7	+2·7	42·0	+0·4	41·5	?	41·0	−1·3
8	25·8	−2·6	40·1	−1·3	41·2	+3·5	30·9	−5·9	42·1	+2·8	44·1	+2·4	47·0	?	40·0	−2·6
9	39·8	+11·1	42·1	+0·1	43 7	+5·9	34·9	−2·0	41·3	+2·5	39·4	−2·8	45·5	?	38·4	−4·7
10	36·8	+7·7	46·1	+3·6	35·2	−2·4	40·0	+2·9	43·8	+5 3	51·3	+8·6	44·0	?	48·7	+5·3
11	27·8	−1·4	41·1	−1·7	30·7	−5·9	31·4	−6·0	39·3	+1·6	46·1	+2·6	37·5	?	55·4	+11·4
12	34·3	+5·4	51·0	+8·4	31·2	−4·7	42·0	+4·7	37·2	+0·4	48·2	+4·1	36·5	?	47·2	+2·9
13	29·3	+0·2	40·6	−2·2	28·2	−7·4	33 9	−3·6	28·8	−7·4	48·2	+4·1	30·5	?	54·4	+10·0
14	23·8	−5·5	37·6	−5·1	28·7	−6·6	32·9	−4 6	31·6	−4·3	47·1	+3·0	31·5	?	47·2	+2·4
15	24·8	−4·5	41·6	−1·3	28·7	−6·3	30 6	−6·7	34·8	−0·6	44·1	+0·4	35·5	?	45·1	+0·5
16	26·3	−3·6	39·1	−4·2	24·7	−10·5	33·9	−3·8	32·4	−3·3	51·8	+8·4	35·5	?	48·7	+4·0
17	18·8	−11·8	39·6	−4·6	25·2	−10·2	31 9	−6·4	33·6	−2·4	46·1	+2·7	35·5	?	46·2	+1·2
18	15·3	−15·2	40·6	−3·7	27·7	−7·7	28·9	−9·6	36·4	+0·4	44·6	+0·9	32·5	?	45·1	−0·2
19	14·8	−16·1	30·5	−13·9	25·7	−9·8	26·4	−12·2	35·0	−1·1	44·1	+0·6	37·0	?	44·6	−0·3
20	15·8	−15·5	37·1	−7·6	37·7	+2·1	32·9	−6·4	37·0	+0·8	39·9	−4·0	40·0	?	38·9	−6·3
21	39·3	+8·1	38·1	−6·6	45·3	+10·1	35·9	−3·3	46·5	+10·9	39·4	−4·9	42·0	?	45·1	−0·2
22	34·8	+3·1	49·0	+4·4	32·7	−2·4	48·0	+8·9	46·5	+10·8	44·1	−0·3	47·5	?	42·0	−2·9
23	31·8	0	46·1	+1·0	34·3	−0·8	45·5	+5·8	36·0	−0·4	52·3	+7·4	35·5	?	58·8	+13·7
24	31·8	+1·1	46·1	+1·1	31·7	−3·2	37·9	−2·4	31·6	−4·8	46·1	+0·6	32·5	?	50·7	+5·0
25	34·8	+5·1	41·6	−2·3	33·7	−0·7	38 9	−1·4	34·6	−1·6	46·1	+0·6	33·5	?	48·2	+2·4
26	33·8	+4·9	55·0	+11·9	36·7	+2·8	42·0	+2·1	38·5	+2·6	49·8	+4·5	38·0	?	50·3	+4·7
27	37·3	+9·5	57·9	+15·1	36·7	+3·1	44·5	+4·8	35·2	0	44·1	−0·7	38·0	?	45·1	−0·3
28	39·8	+12 5	55·0	+12 7	32·2	−0·9	49·0	+10·1	42·1	+7·7	53·3	+9·1	41·0	?	48·2	+3·4
29	30·8	+3·1	47·1	+4·9	31·2	−1·7	49·0	+10·7	35 6	+1·7	55·7	+11·9	37·5	?	55·9	+11·7
30	29·3	+1·4	41·1	−1·5	28·2	−4·7	45·0	+7·2	28·6	−4·9	53·8	+10·3	32·0	?	53·9	+10·2
31	26·3	−2·3	42·1	−1·4	26 7	−6·5	44·0	+6·0	24·0	−9·7	43·6	+0·4	28·0	?	43·1	−0·3
Mean.	29·4	+0·2	42·7	−0·1	34·5	−1·0	31·3	−0·6	37·9	+1·5	46·1	+2·6	38·6	?	46·2	+2·0

Table II.—Continued.

Date.	Ranikhet.		Bareilly.		Darjeeling.		Dhubri.		Abu.		Deesa.		Pachmarhi.		Hoshangabs.	
	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.	Actual.	Variation.
1	46·0	+6·5	41·3	−2·7	33·8	−1·1	53·5	+0·1	51·0	−0·5	51·9	+1·0	39·3	−7·2	47·3	−4·4
2	50·0	+10·7	41·3	−2·9	35·2	+0·8	53·0	0	54·9	+3·7	51·9	+1·0	38·3	−8·1	42·8	−8·9
3	50·0	+10·5	39·8	−4·6	35·9	+1·3	53·0	+0·1	59·9	+9·0	50·9	−0·1	40·8	−5·3	44·8	−7·1
4	56·0	+16·6	46·8	+2·1	37·9	+3·3	52·5	−0·9	55·9	+4·8	51·4	+0·1	43·3	−2·6	48·3	−3·7
5	47·0	+7·1	46·8	+2·2	35·7	+1·1	54·9	+1·3	52·9	+1·5	52·4	+0·9	47·3	+0·9	48·8	−3·6
6	45·0	+4·6	47·3	+2·8	35·3	−0·1	54·9	+1·2	53·9	−2·4	50·4	−1·2	46·3	−0·3	50·3	−1·8
7	44·0	+3·1	45·3	+1·0	35·1	−0·5	53·9	+0·5	56·9	+5·4	55·4	+4·2	53·2	+6·6	57·8	+5·9
8	49·0	+8·0	40·3	−4·2	36·7	+0·5	53·5	+0·2	59·9	+8·7	60·8	+10·0	61·2	+14·3	53·3	+1·4
9	47·0	+5·8	40·8	−3·9	35·7	−0·7	53·5	+0·7	58·9	+8·0	58·9	+8·3	49·2	+1·5	54·8	+2·9
10	49·0	+8·0	45·8	+0·6	34·3	−2·3	53·5	+0·6	59·9	+9·4	59·9	+9·2	50·2	+2·0	56·3	+4·1
11	41·0	+0·5	50·3	+4·4	35·4	−1·0	54·4	+1·5	56·9	+6·8	56·9	+6·5	50·7	+2·0	54·3	+1·4
12	40·0	+0·3	48·3	+1·8	36·7	+0·7	53·0	−0·3	51·0	+1·1	57·4	+6·7	51·7	+3·1	57·3	+4·1
13	36·0	−3·6	52·3	+5·6	Not recorded		53·9	+0·6	51·0	+0·6	53·9	+2·3	55·2	+6·7	55·8	+2·6
14	34·0	−5·3	48·3	+1·5	37·3	+1·7	58·9	+5·4	49·5	−1·3	54·9	+2·8	49·7	+1·4	54·3	+0·9
15	40·0	+1·0	51·3	+4·5	35·1	−0·2	57·4	+4·2	48·0	−3·5	53·4	+0·9	49·2	+0·9	53·3	−0·1
16	40·0	+0·6	51·3	+4·5	35·2	−0·1	55·9	+2·5	50·5	−1·3	56·4	+3·3	52·2	+4·4	57·3	+4·2
17	38·0	−2·0	49·8	+3·2	Not recorded		54·9	+1·6	51·9	−0·4	53·4	+0·1	58·7	+10·6	61·3	+7·9
18	41·0	+1·0	50·3	+3·4	38·1	+3·3	54·9	+1·3	53·4	+1·2	56·9	+4·3	56·7	+8·3	57·8	+4·3
19	41·0	+1·2	50·3	+3·5	37·5	+3·0	55·4	+1·6	47·5	−4·5	50·9	−1·2	51·7	+3·8	55·3	+2·1
20	44·0	+4·4	41·3	−5·2	39·1	+4·8	56·9	+2·8	51·5	−0·5	55·9	+4·2	50·7	+3·2	60·3	+7·0
21	44·0	+4·9	44·8	−1·6	38·8	+4·7	53·9	−0·2	57·9	+5·9	53·9	+2·9	50·2	+2·4	55·8	+2·7
22	51·0	+12·2	42·8	−3·4	38·1	+4·9	54·9	+0·8	61·4	+9·4	56·4	+5·6	50·7	+3·5	55·3	+3·2
23	46·0	+6·9	53·8	+7·7	37·2	+3·9	53·0	−1·0	56·4	+4·1	61·8	+10·6	57·2	+10·3	56·8	+5·0
24	33·0	−6·3	53·3	+6·9	35·6	+2·4	56·9	+3·0	48·0	−4·1	58·4	+7·0	48·2	+0·4	55·3	+3·2
25	39·0	−0·1	42·3	−4·9	32·4	−1·2	54·9	+0·8	50·0	−1·1	49·5	−1·0	46·8	−1·0	56·8	+4·9
26	43·0	+4·2	49·3	+2·2	35·7	+2·3	53·0	−1·2	54·4	+4·3	53·9	+3·8	55·2	+8·2	57·8	+6·4
27	43·0	+4·8	47·3	+0·2	35·9	+2·0	53·9	−0·3	58·9	+9·6	59·9	+10·4	61·2	+14·3	59·3	+8·1
28	46·0	+8·3	50·3	+3·5	36·1	+2·7	55·9	+1·9	58·4	+9·7	63·3	+14·1	53·2	+6·7	58·8	+7·7
29	40·0	+2·4	56·8	+10·4	38·2	+4·7	55·4	+1·7	53·4	+4·9	60·4	+11·1	60·7	+15·0	60·8	+10·1
30	37·0	−0·9	58·8	+12·8	39·2	+6·3	60·4	+7·2	46·0	−2·8	57·9	+8·1	62·2	+16·8	62·3	+11·7
31	32·0	−6·2	50·3	+4·6	33·7	+1·4	55·4	+2·5	44·1	−5·6	57·9	+7·5	54·2	+8·6	59·3	+8·1
Mean.	43·0	+3·5	47·7	+1·8	36·2	+1·8	54·8	+1·3	53·7	+2·8	55·7	+4·6	51·4	+4·2	55·2	+2·7

Table III. giving the difference day by day of the maximum temperature at 8 selected pairs of stations (viz., each pair consisting of a hill station and adjacent plain station) named in the headings.

1889.	Quetta & Jacobabad.	Murree & Rawalpindi.	Simla & Ludhiana.	Mussooree & Roorkee.	Ranikhet & Bareilly.	Darjeeling & Dhubri.	Mt. Abu & Dessa.	Pachmarhi & Hoshangabad.	General character of weather.
Jan. 1	23·8	10·9	13·7	14·8	11·5	29·7	18·1	9·8	Barometer rising, clear.
2	12·9	12·0	13·0	16·8	11·0	30·2	15·6	9·3	Do. ,, light cloud, Punjab.
3	13·9	11·4	13·5	10·8	5·1	27·7	16·1	7·9	Do. falling, cloud plains and hills.
4	20·3	10·0	10·8	8·8	6·1	24·3	16·6	8·3	Do. ,, clouds, Punjab and Hills.
5	26·3	19·9	15·9	11·8	9·1	23·3	19·6	8·3	Do. rising, rapidly, skies cloudy.
6	21·3	16·4	23·1	18·8	12·5	27·2	19·1	10·3	Do. ,, Sky clear.
7	18·8	13·4	21·6	23·8	18·4	31·7	19·1	8·3	Do. ,, do. do.
8	21·3	11·9	13·0	17·3	12·0	30·2	17·7	8·8	Do. falling, no clouds.
9	18·4	13·4	14·0	11·8	10·5	27·7	21·2	9·8	Do. ,, light cloud.
10	13·8	9·4	15·5	12·8	13·0	30·7	20·2	10·3	Do. ,, do. ,,
11	28·3	27·8	20·7	18·3	17·0	26·3	20·1	10·9	Do. ,, Moderate cloud.
12	30·9	20·4	21·4	24·8	19·5	29·7	19·6	9·8	Do. ,, Skies clouded, especially hills.
13	28·4	19·4	16·0	13·3	20·9	?	18·5	9·8	Do. rising, Snow on hills
14	29·9	17·4	27·2	18·8	20·9	25·8	20·0	8·8	Do. ,, Clear over plains, overcast hills.
15	30·9	21·9	28·9	24·3	20·9	26·8	19·5	7·4	Do. ,,
16	25·9	18·4	25·9	15·8	21·9	29·3	18·0	7·3	Do. ,, Snow on hills.
17	36·5	23·1	26·9	21·8	18·7	?	15·5	8·9	Do. ,, Generally clear.
18	39·5	18·4	23·1	26·3	19·4	31·3	16·5	9·9	Do. falling.
19	36·5	18·5	21·1	24·3	24·9	27·3	14·0	11·3	Do. rising.
20	16·3	16·4	15·7	23·3	19·9	28·8	13·0	10·8	Do. falling, clear.
21	15·3	5·0	14·7	22·3	10·1	23·8	16·1	6·3	Do. ,,
22	20·8	10·4	11·4	14·8	7·1	31·2	18·7	9·9	Do. ,, Snow storm Murree & Quetta.
23	28·9	23·5	15·9	23·8	12·1	31·7	17·6	11·4	Do. ,, Snow storm hill stations.
24	30·9	24·9	18·5	18·8	3·8	30·3	20·0	9·9	Do. rising rapidly, snow on hills, rain on plains.
25	21·8	19·9	23·1	22·8	13·3	30·2	19·0	8·8	Do. ,,
26	23·3	15·4	20·7	21·8	16·9	27·8	19·1	8·8	Do. ,, Moderate cloud, Upper India.
27	33·4	16·4	21·9	16·3	18·9	28·8	19·1	12·8	Do. falling, Moderate cloud.
28	26·9	13·4	17·0	22·3	15·5	34·7	17·1	8·4	Do. ,, rapidly, rain N. Punjab.
29	27·9	15·6	11·6	12·8	17·0	32·2	17·2	7·9	Do. ,, very rapidly, overcast N. India.
30	25·9	16·1	20·1	19·3	11·0	28·8	21·5	8·9	Do. ,, Snow on hills, rain in plains.
31	35·0	21·6	21·7	24·3	12·9	23·6	21·0	10·3	Do. rising very rapidly, snow on hills.
Mean ...	25.3	16·5	18·6	18·6	14·6	28·7	18·2	9·3	
Nor. mean	21·7	15·5	11·4	17·3	16·1	29·1	15·1	9·5	
Diff. from Normal ...	+3·6	+1·0	+7·2	+1·3	−1·5	−0·4	+3·1	−0·2	

The following table (Table IV) gives the differences day by day of the night or minimum temperature at the pairs of stations named in the headings, a negative sign indicating that the night temperature was higher at the hill than at the corresponding plain station.

Table IV.

1889.	Quetta & Jacobabad.	Murree & Rawal Pindi.	Simla & Ludhiana.	Mussooree & Roorkee.	Ranikhet & Bareilly.	Darjeeling & Dhubri.	Mt. Abu & Deesa.	Pachmarhi & Hoshangabad.
Jan. 1	11·8	−6·8	0·7	−3·1	−4·7	19·7	0·9	8·0
2	8·8	−8·4	−4·1	−2·6	−8·7	17·8	−3·0	4·5
3	8·3	−12·4	−2·8	−5·7	−10 2	17·1	−9·0	4·0
4	4·8	−5·4	−4·6	−3·4	−9·2	14·6	−4·5	5·0
5	17·8	3·7	8·5	3·7	−0·2	19·2	−0·5	1·5
6	13·3	−2·8	5·3	4·1	2·3	19·6	−3·5	4·0
7	4·3	−4·8	0·3	−0·5	1·3	18·8	−1·5	4·6
8	14·3	−10·3	2·0	−7·0	−8·7	16·8	0·9	−7·9
9	2·3	−8·8	−1·9	−7·1	−6·2	17·8	0	5·6
10	9·3	4·8	7·5	4·7	−3·2	19·2	0	6·1
11	13·3	0·7	6·8	17·9	9·3	19·0	0	3·6
12	16·7	10·8	11·0	10·7	8·3	16·3	6·4	5·6
13	11·3	5·7	19·4	23·9	16·3	?	2·9	0·6
14	13·8	4·2	15·5	15·7	14·3	21·6	5·4	4·6
15	16·8	1·9	9·3	9·6	11·3	22·3	5·4	4·1
16	12·8	9·2	19·4	13·2	11·3	20·7	5·9	5·1
17	20·8	6·7	12·5	10·7	11·8	?	1·5	2·6
18	25·3	1·2	8·2	12·6	9·3	16·8	3·5	1·1
19	15·7	0·7	9·1	7·6	9·3	17·9	3·4	3·6
20	21·3	−4·8	2·9	−1·1	−2·7	17·8	4·4	9·6
21	−1·2	−9·4	−7·1	3·1	0·8	15·1	−4·0	5·6
22	14·2	15·3	−2·4	−5·5	−8·2	16·8	−5·0	4·6
23	14·3	11·2	16·3	23·3	7·8	15·8	5·4	−0·4
24	14·3	6·2	14·5	18·2	20·3	21·3	10·4	7·1
25	6·8	5·2	11·5	14·7	3·3	22·5	−0·5	10·0
26	21·2	5·3	11·3	12·3	6·3	17·3	−0·5	2·6
27	20·6	7·8	8·9	7·1	4·3	18·0	1·0	−1·9
28	15·2	16·8	11·2	7·2	4·3	19·8	4·9	5·6
29	16·3	17·8	20·1	18·4	16·8	17·2	7·0	0·1
30	11·8	16·8	25·2	21·9	21·8	21·2	11·9	0·1
31	15·8	17·3	19·6	15·1	18·3	21·7	13·8	5·1
Mean ...	13·3	3·1	8·2	7·7	4·7	18·6	2·0	3·7
Normal mean	13·6	2·4	7·1	8·5	6·4	18·9	0·2	5·3
Diff. from normal	−0·3	+0·7	+1·1	−0·8	−1·7	−0·3	+1·8	−1·6

An examination of the preceding data shews that there were three periods in Jannary 1889 during which the minimum temperature of the hill stations was in excess of that at the neighbouring plain stations. These were—

1st, From the 1st to the 4th.

2nd. From the 8th to the 11th.

3rd. From the 20th to the 22nd.

The abnormal temperature relations were most marked during the first period, and we shall therefore use chiefly the data of that period in the discussion.

During the first period extending from the 1st to the 4th the minimum temperature was on every night several degrees higher at the hill stations than at the adjacent plain stations. The minimum temperature on the night of the 3rd for example was $12\frac{1}{2}°$ higher at Murree than at Rawalpindi, 3° higher at Simla than at Ludhiana, 5° higher at Mussooree than at Roorkee, and 10° higher at Ranikhet than at Bareilly.

The following method of stating the facts will shew that the inversion of the temperature relations was not confined to the neighbourhood of the hills only. On the night of the 3rd (or early morning of the 4th) the minimum temperature at Murree, Simla, Ranikhet, and Mussooree was higher than at all the plain stations in the Punjab, North-Western Provinces (except Jhansi), Rajputana, Sind, Central India, and the greater part of Behar and Bengal and the Central Provinces.

The following statement gives exact data for representative stations in each province.

Hill stations.	Minimum temperature 3rd January.	Province.	Plain stations.	Minimum temperature 3rd January.	Difference between minim. temp. of Murree and plain stations.	Difference between minim. temp. of Simla and plain stations.	Difference between minim temp. of Ranikhet and plain stations.
Murree ...	49·3	Punjab	Rawalpindi	36·9	−12·4	−11·5	−13·1
			Lahore	37·2	−12·1	−11·2	−12·8
Simla ...	48·4		Sirsa	39·1	−10·2	−9·3	−10·9
		Sind	Jacobabad	38·6	−10·7	−9·8	−11·4
		Rajutana	Jeypore	42·2	−7·1	−6·2	−7·8
			Indore	44·8	−4·5	−3·6	−5·2
		Central Provinces	Nagpur	50·2	+0·9	+1·8	+0·2
			Khandwa	44·0	−5·3	−4·4	−6·0
			Jubbulpore	38·9	−10·4	−9·5	−11·1
		Berar	Akola	43·2	−6·1	−5·2	−6·8
		Bombay	Malegaon	44·5	−4·8	−3·9	−5·5
			Poona	49·0	−0·3	+0·6	−1·0
Chakrata	53·6	N. W. Provinces	Agra	43·6	−5·7	−4·8	−6·4
			Lucknow	41·0	−8·3	−7·4	−9·0
Ranikhet	50·0		Allahabad	42·7	−6·6	−5·7	−7·3
		Behar	Patna	46·9	−2·4	−1·5	−3·1
			Durbhunga	50·4	+1·1	+2·0	+0·4
		Bengal	Hazaribagh	49·3	0	+0·9	−0·7
			Calcutta	48·8	−0·5	+0·4	−1·2
			Burdwan	48·3	−1·0	−0·1	−1·7
			Jessore	46·9	−2·4	−1·5	−3·1
			Burrisal	49·1	−0·2	+0·7	−0·9
			Dacca	54·2	+4·9	+5·8	+4·2
			Saugor Island	51·2	+1·9	+2·8	+1·2
		Assam	Dhubri	53·2	+3·9	+4·8	+3·2

The minus sign in the preceding table indicates that the plain station to which it refers had a lower minimum temperature than the hill station with which it is compared and the plus sign that it had a higher temperature.

The preceding table shews over what an extensive area in Northern and Central India it is possible for the minimum temperature to be considerably (from 1° to 12°) below that of the hill stations in Upper India.

Table I. shews that the inversion of temperature obtained on at least eleven nights during the month. The following examples from previous years, which examination shews to be fairly average cases, will indicate to what extent the temperature variations of January 1889 were abnormal. In January 1888 the night temperature of Mussooree ranged from 5·6° above that of Roorkee to 21·8° below it (giving a total range of 27·4). The average difference of temperature was 8·1° for the month, which is almost identical with the normal average (8·5°). The minimum temperature at Mussooree was in excess of that of Roorkee on only three nights of the month. In January 1886 the night or minimum temperature at Simla ranged from 2·8° above that at Ludhiana to 23·5° below (giving a total range of 26·3°) and was above that at Ludhiana on three nights only during the month. The difference between the minimum temperatures at these two stations averaged 10°. It is not necessary to multiply cases, as all that have been examined give similar evidence. Hence it appears that in ordinary seasons the minimum temperature may be on two or three nights in January in slight excess at the hill stations of Upper India as compared with the adjacent plain stations of the Punjab and North-Western Provinces. These figures hence establish that, although inversion of the normal vertical temperature relations is not infrequent in the month of January in Upper India, it was of abnormal frequency in January 1889. It was undoubtedly related to or connected with the holding off of the winter rains in that month. Anticyclonic conditions prevailed in Upper India with unusual persistency, and it was not until the end of the month that general rain accompanying a depression and cold weather storm occurred in the plains and heavy general snow in the hills. Hence the high temperature was undoubtedly associated with anticyclonic conditions of pressure, as has been found to be the case in Europe and the United States during similar vertical temperature relations, and also with the protracted delay in the depression of the snow line in the hills during winter produced by general snowfall.

The preceding paragraphs have stated fully one important feature of the anomalons temperature conditions of the month of January 1889. Before proceeding to discuss the causes of these features, it is desirable to trace the varying temperature relations between the plains and the hills in Upper India more exactly. There are three prominent types of weather conditions and relations in the hills and plains of Upper India during the cold weather. These are as follows :—

1st.—The prevalence of fine clear weather with light winds or calms in the hills and plains. These conditions accompany prolonged anticyclonic pressure conditions of moderate intensity in Upper India, and may be described as " ordinary anticyclonic conditions." They obtain frequently during the cold weather.

2nd.—The prevalence of disturbed or stormy weather in the hills and plain districts. This type of weather is due to the formation, passage, or existence of cold weather depressions. Skies are heavily clouded, rain falls more or less generally in the plains of Upper India, and heavy general snow is received in the higher mountain regions down to a level determined chiefly by the intensity of the storm. Winds are weak in the plains, but their directions usually indicate feebly marked cyclonic circulation about an ill-defined centre. The winds are on the other hand often strong or violent and the weather very stormy in the hill districts for periods varying in length from a few hours to several days. These periods may be described as those of " cold weather cyclonic storms."

3rd.—The prevalence of unusually bright clear cool weather such as always obtains over the whole of Northern India, after the breaking up of a large and well marked cold weather storm. In this case, a strong and steady cool westerly current flows from Upper India and the adjacent hills over the whole of Northern India as far east as the Bengal coast. The air is remarkably dry and bracing. The change of conditions is most marked in Bengal, where the weather during the previous unsettled period is usually damp, cloudy, and warm, with light southerly winds.

These are the three chief types of weather in Northern India during the cold weather period extending from November to February or March. They merge into each other, more especially (3) and (1). Again it frequently happens that small depressions pass over Upper India which give a brief period of cloudy weather without rain in the plains, and light local rain or snow showers in the hills. The precipitation in this case is almost entirely confined to the higher elevations. This type of weather gives rise to somewhat different temperature relations than (2). They will, however, be included in (2) as it is hardly possible to differentiate between all the numerous varieties of cold weather storms.

The temperature conditions and relations in ordinary anticyclonic weather in Upper India will be sufficiently shewn by the following data given in three small tables for the two pairs of stations, Murree and

Rawalpindi and Simla and Ludhiana. The first table gives the daily range of temperature at three pairs of stations on six days of January 1889, when anticyclonic conditions accompanying inversion of vertical temperature relations obtained in Upper India.

Day of month.	Murree.	Rawal-pindi.	Simla.	Ludhiana.	Ranikhet.	Bareilly.
3rd	9·8°	33·6°	13·3°	29·6°	16·1°	31·4°
4th	13·8°	29·2°	20·8°	36·2°	15·1°	30·4°
8th	13·5°	35·7°	17·6°	28·6°	14·2°	34·9°
9th	14·9°	37·1°	16·9°	32·8°	15·2°	31·9°
21st	18·8°	33·2°	13·0°	34·8°	20·1°	29·4°
22nd	?	?	15·8°	29·6°	15·1°	30·4°
Mean daily range of selected periods ...	14·2°	33·8°	16·1°	31·9°	16·0°	31·4°
Normal daily range of selected periods ...	13·1°	27·0°	15·3°	25·0°	14·9°	24·9°
Difference ...	+1·1°	+6·8°	+0·8°	+6·9°	+1·1°	+6·5°

This table shews a considerable amount of irregularity at the hill stations in the daily range of temperature during these periods of inversion of night temperature. On the other hand the daily range of temperatnre at the level of the plains is always excessive and approximately uniform as shewn by the Rawalpindi and Ludhiana data.

The following table gives the variations of the maximum and minimum temperature on the same days at the hill stations from their normal values at the same stations, a plus sign indicating that temperature was in excess and a minus sign that it was below the normal.

Day of month.	Murree.		Simla.		Ranikhet.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
3rd	+ 9·7°	+12·6°	+ 9·5°	+11·6°	+10·7°	+10·5°
4th	+ 9·6°	+ 8·4°	+14·4°	+ 9·0°	+15·7°	+16·6°
8th	+ 3·8°	+ 3·5°	+ 5·2°	+ 2·8°	+ 7·2°	+ 8·0°
9th	+ 7·8°	+ 5·9°	+ 4·5°	+ 2·5°	+ 6·1°	+ 5·8°
21st	+16·8°	+10·1°	+ 8·5°	+10·9°	+11.2°	+ 4·9°
22nd	?	?	+11·6°	+10·8°	+13·7°	+12·2°
Mean variation from normal during periods ...	+9·5°	+8·1°	+9·0°	+7·9°	+10·8°	+9·7°

This table shews conclusively that during these periods of inverted temperature relations temperature was excessive at the hill stations and the excess was nearly as marked in the night as in the day temperature.

The following gives similar data for the neighbouring plain stations :—

Day of month.	Rawalpindi.		Ludhiana.		Bareilly.	
	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
3rd	+6·4°	+0·8°	+7·0°	+3·6°	+0 7°	−4·6°
4th	+4·3°	+3·1°	+9·6°	−0·6°	+1·7°	+2·1°
8th	+2·3°	−5·9°	+5·6°	+2·4°	+5·2°	−4·2°
9th	+7·8°	−2·0°	+5·2°	−2·8°	+2·7°	−3·9°
21st	+5·9°	−3·3°	+6·4°	−4·9°	+4·7°	−1·6°
22nd	...	...	+5·6°	−0·3°	+3·6°	−3·4°
Average ...	+5·3°	−1·5°	+6·6°	−0·4°	+3·1°	−2·6°
Range of variation ...	6·8°		7·0°		5·7°	

These figures are very consistent and establish that in these periods under discussion the day temperature was considerably above the average at the plain stations and the night temperature was generally below it but by smaller amounts. They also shew that what may be termed the range of variation from the normal diminished from west to east in the plain of Northern India.

Hence it may be inferred that the temperature conditions of periods of ordinary anticyclonic weather in Upper India are :—

(*a.*)—Increased day and night temperatures at the hill stations, the excess being nearly as great in the night as it is in the day temperatures, so that practically the daily range is unaltered.

(*b.*)—Increased day and decreased night temperature and hence a much greater daily range of temperature at the plain stations.

(*c.*)—When these conditions are most pronounced, in consequence of the opposite variations of the night temperatures at the hill and plain stations, the minimum temperature is occasionally during such periods several degrees higher at the hill stations than in the adjacent plains. The data for January 1889 also shew that the low temperature in the plains, more especially when compared with the hill stations, is not a phenomenon of valleys or of the low lying districts in the immediate neighbourhood of the hills, but may extend over the whole of Northern and Central India, and therefore to a distance of some hundreds of miles from the mountains of Northern India.

The same tables (I to IV) also give three examples of very low temperature of the hill stations during stormy weather. These are :—

1*st*, the night of the 13th.

2nd, the night of the 23rd.

3rd, the nights of the 30th and 31st.

The last is the most striking example and is therefore best adapted to illustrate the temperature relations between the hills and plains during cold weather storms.

The following gives a brief description of the character of these disturbances taken from the India monthly weather report for January 1889.

"The barometer began to fall briskly on the afternoon of the 8th in Upper Sind and Beluchistan, and a very shallow depression was formed on the 9th, which followed the same course as the previous disturbance and gave moderately heavy snow to the Punjab Himalayas on the 10th, and brought the snow line down to below 9,000 feet. The weather continued somewhat disturbed in Northern India for three days longer, and light showers fell at the hill stations on the 12th, and in Behar, Chutia Nagpore, and Central Bengal on the 13th. Pressure increased steadily until the 17th, when very strongly marked anti-cyclonic conditions, with fine, clear, cool weather and strong westerly or north-westerly winds, prevailed over the whole of Northern India. The highest pressures of the month were recorded on the morning of the 17th, the absolute maximum being 30·38″ at Peshawar. No change of importance occurred untill the 22nd, when the barometer fell briskly in North-Western India. The disturbance then initiated differed considerably in character from the previous. There were two separate areas of disturbance in which the barometer fell rapidly, and more or less general rain was received. The first included the Punjab Himalayas and adjacent plains from Sealkot to Roorkee, and the second comprised the greater part of Rajputana and Indore. The disturbance in the Punjab passed away after giving moderate snow in the hills on the afternoon of the 23rd and light showers in the adjacent plains. That which originated in Rajputana drifted during the next two days eastward into East Bengal and Burma, and gave moderate general rain to the North-Western Provinces, Central India, and light local showers in Behar, Bengal, and Assam. A short interval of fine weather followed until the afternoon of the 27th, when the first large and important cold weather storm of the year was initiated. It was, like the previous, a double disturbance. It consisted in part of a shallow depression which passed into Sind from Beluchistan on the 28th and advanced during the next three days in an east-south-east direction across the head of the Peninsula into Upper Burma, to which it gave cloudy weather on the 1st February. It apparently filled up very slowly in that area and gave low pressure in Burma until the 5th. The appearance of this depression in Sind on the

28th was followed on that day by a very rapid fall of the barometer in the North Punjab and the formation of an independent deep depression, the centre of which was to the north of Rawalpindi and Peshawar on the morning of the 29th. It intensified considerably during the day and marched slowly to the south-east along the hills, to which it gave very stormy weather and heavy snowfall during the next forty-eight hours. A very rapid rise of the barometer set in on the 31st, and the depression filled up very rapidly. This deep depression very largely modified the distribution of pressure over the whole of North-Western and Central India, and obscured the shallow depression in Central India on the 29th and 30th; but with the disappearance of the former on the 31st, the latter again became clearly marked and formed the chief feature of the weather during the next two days. The double disturbance gave a large general and much needed supply of rain to the greater part of Northern India, including the Punjab, Rajputana, Central India, the North-Western Provinces and Behar, and showers in Bengal."

The following gives the precipitation at the hill stations during the storm :—

	January 1889.					February 1889.		Total fall during period.
	27	28	29	30	31	1	2	
Murree ...	–	0·71	2·49	2·45	0·75	1·05	–	6·75
Simla ...	0·07	–	0·78	1·93	1·65	0·30	–	4·73
Chakrata...	–	–	0·75	2·98	1·44	0·28	–	5·45
Ranikhet...	–	–	0·90	2·52	1 92	0·25	–	5·59

At the three first named stations rain and sleet fell during the earlier part of the disturbance, but it changed afterwards to snow, which fell steadily during the night of the 30th and the greater part of the 31st and 1st, when the weather cleared up rapidly. At Ranikhet little or no snow fell. The depth of snow at the end of the storm at Simla was quite three feet, at Chakrata about the same, and at Murree about five feet. The nights of the 30th and 31st were hence stormy with strong winds, thick cloud, and constant snowfall. The cloud canopy extended over the greater part of Northern India, or over the East Punjab, N.-W. Provinces, Behar, and East Rajputana.

The following gives the minimum temperature on these nights at Simla and at a large number of stations in the plains.

Date.	Hill station.	Minimum temperature. A.	Plain station.	Province.	Minimum temperature. B.	Difference between hills and plains. B—A
Night of 30th Jan. 1889.	Simla	28·6°	Ludhiana	Punjab	53·8°	25·2°
			Lahore	Punjab	49·0°	20·4°
			Lucknow	N.-W. P.	58·9°	30 3°
			Allahabad	N.-W. P.	59·2°	30·6°
			Patna	Bengal	59·8°	31·2°
			Calcutta	Bengal	62·3°	33·7°
			Jeypore	Rajputana	54·1°	25·5°
			Nagpur	Central Provinces	62·3°	33·7°
			Deesa	Bombay	57·9°	29·3°
			Jacobabad	Sind	41·1°	12·5°
Do. of 31st Jan. 1889.	Simla	24·0°	Lahore	Punjab	42·1°	18·1°
			Lucknow	N.-W. P.	56·9°	32·9°
			Allahabad	N.-W. P.	59·7°	35·7°
			Patna	Bengal	59·8°	35·8°
			Calcutta	Bengal	61·8°	37·8°
			Jeypore	Rajputana	41·2°	17·2°
			Nagpur	Central Provinces	59·3°	35·3°
			Deesa	Bombay	57·9°	33·9°
			Jacobabad	Sind	42·1°	18·1°

These figures indicate that over the whole of the plains of Northern India the minimum night temperature was from 20° to 30° higher than at the hill stations of Upper India. These very large differences (in the opposite directions to those discussed in the previous case) were mainly due to the abnormally low temperature in the hills, and in part to the increased night temperature in the plains due to the presence of clouds diminishing radiation. The characteristic features of these periods will be best shewn by examining the whole of the temperature data of the same stations as in the previous case.

The following gives the daily range of temperature on six days of the month during these stormy weather periods.

Date.	Murree.	Rawalpindi.	Simla.	Ludhiana.	Ranikhet.	Bareilly.
11th	12·0°	28·5°	9·2°	23·1°	17·2°	24·9°
13th	14·0°	27·7°	21·9°	18 5°	19·3°	23·9°
23rd	3·3°	15·6°	14·3°	13·9°	18·1°	22·4°
24th	10·5°	29·2°	10·6°	14·6°	24·3°	7·8°
30th	8·4°	7·7°	14·5°	9·4°	21·2°	10·4°
31st	5·9°	10·2°	15·5°	17·6°	25·3°	19·9°
Average daily range during selected periods ...	9·0°	19·5°	14·3°	16·2°	20·9°	18·2°
Normal daily range of month...	12·3°	25·4°	14·8°	24·1°	14·5°	24·2°

The figures show that at such periods the daily range is slightly diminished at the hill stations, but is very greatly reduced at the plain stations.

The following table gives the variations from the normal of the maximum and minimum temperatures on the same dates at the hill stations, a plus sign indicating excess and a minus sign defect.

	Simla.		Murree.		Chakrata.	
Date.	Maximum.	Minimum.	Maximum.	Minimum.	Maximum.	Minimum.
11th	−3·3°	+1·6°	−6·2°	−5·9°	−2·8°	+0·8°
13th	−0·3°	−7·4°	−6·2°	−7·4°	+3·6°	+1·8°
23rd	−0·3°	−0·4°	−8·7°	−0·8°	+16·8°	+2·4°
24th	−8·4°	−4·8°	−3·5°	−3·2°	+4·2°	−0·9°
30th	−6·0°	−4·9°	−8·4°	−4·7°	+2·2°	−3·2°
31st	−9·3°	−9·7°	−13·1°	−6·5°	−10·7°	−5·0°
Mean.	−4·6°	−4·3°	−7·7°	−4·8°	+2·2°	−0·7°

This table shows that during these periods the night and day temperatures at the hill stations were considerably reduced below the normal and by nearly equal amounts.

The Chakrata observations at this period, it should be noted, were apparently vitiated by large occasional errors, but in examining their figures it should be taken into consideration that the only stormy weather which influenced Chakrata was that of the 30th and 31st.

The following table gives similar data for the adjacent plain stations.

	Ludhiana.		Rawalpindi.		Roorkee.	
Date.	Maximum.	Minimum.	Maximum	Minimum.	Maximum.	Minimum.
11th	+2·1°	+2·6°	+6·6°	+6·0°	+0·7°	+11·4°
13th	−0·4°	+4·1°	−2·1°	−3·6°	+2·1°	+10·0°
23rd	−1·6°	+7·4°	−1·1°	+5·8°	+6·7°	+13·7°
24th	−7·0°	+0·6°	+5·2°	−2·4°	−4·4°	+5·0°
30th	−4·2°	+10·3°	−9·4°	+7·2°	−7·5°	+10·2°
31st	−6·3°	+0·4°	−8·2°	+6·0°	−11·1°	−0·3°
Mean.	−2·9°	+4·2°	−1·5°	+3·3°	−2·3°	+8·3°

These data shew that at the plain stations the range of temperature was diminished not only by decreased day temperature but also by increased night temperature to an equal or greater amount. Hence during these storms the temperature was reduced at the hill stations throughout, whereas at the plain stations it was raised at night by amounts nearly equal to the decrease in the daytime, and there was practically no alteration in the daily range at the hill stations, whereas it was largely reduced at the plain stations.

It hence follows that the temperature relations which obtain during stormy weather accompanied with snow in the hills and rain showers in the plains are:—

1*st.* Diminished temperature throughout the whole day at the hill stations and hence the maximum and minimum temperatures are reduced below the normal by nearly equal amounts and the daily range of temperature is only slightly affected.

2*nd.* At the plain stations temperature is below the normal to a moderate extent in the day, and is considerably above it at night, and hence the daily range of temperature is very considerably reduced.

3*rd.* In consequence of the decreased night temperature at the hill stations and increased night temperature at the plain stations, the differences of the minimum temperature at hill stations and adjacent plain stations are then exaggerated and are occasionally 10° to 15° greater than the average differences.

The third type of temperature relations which obtain in the cold weather in Northern India are those which hold during the fine clear weather and strongly marked anticyclonic conditions that follow a severe cold weather storm. There is no marked example in the temperature data of January 1889. The conditions are shewn in the weather which followed the snow storms of the 30th, 31st January, and 1st February in the hills of Upper India.

The account of the storm has been given in a preceding paragraph. The snowfall which it gave was far heavier in the Punjab Himalayas than in the N.-W. Provinces and Nepal hills. At Simla an average depth of 3 feet lay on the ground at the end of the storm. The weather cleared up in the Punjab on the 1st, and fine clear weather prevailed for some days. The skies cleared in the N.-W. Provinces on the 2nd and 3rd, and in Bengal on the 4th and 5th.

The two following tables give the maximum temperatures and their variations from the normal at eight typical stations in Northern India during the period from the 30th January to 5th February.

Station.	Maximum temperature.						
	Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree ...	32 6°	34·1°	40 7°	43·7°	47·7°	53·7°	45·7°
Simla ...	39·5°	28·8°	35·8°	36·5°	41·3°	51·2°	51·5°
Lahore ...	58·5°	60·5°	60·0°	58·0°	62·5°	65·5°	67·0°
Roorkee ...	58·3°	65·8°	62·8°	59·8°	62·8°	64·8°	68·3°
Lucknow ...	73·1°	70·1°	69·1°	67·1°	67·1°	68·6°	71·6°
Patna ...	65·2°	68·2°	67·7°	67·7°	70·2°	69·2°	68·2°
Burdwan ...	81.5°	84·0°	76·5°	76·0°	78·0°	74·5°	74·5°
Calcutta ...	82·5°	83·5°	76·0°	72·5°	75·5°	73·5°	74·5°

Station.	Variation from normal of maximum temperature of						
	Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree ...	−13·1°	−11·4°	−4·7°	−1·2°	+3·1°	+8·7°	+0·1°
Simla ...	−9·3°	−20·8°	−13·1°	−12·4°	−8·2°	+0·7°	+0·1°
Lahore ...	−9·7°	−7·8°	−8·2°	−10·2°	−5·5°	−2·5°	−1·1°
Roorkee ...	−11·1°	−3·9°	−7·0°	−10·4°	−7·9°	−6·4°	−3·2°
Lucknow ...	−0·8°	−3·8°	−5·3°	−7·8°	−8·6°	−7·5°	−4·8°
Patna ...	−8·4°	−5·6°	−6·3°	−6·5°	−4·5°	−5·9°	−7·4°
Burdwan ...	+2·3°	+4·8°	−2·7°	−3·7°	−2·2°	−6·4°	−6·9°
Calcutta ...	+4·9°	+5·9°	−1·6°	−5·5°	−3·8°	−5 7°	−5·2°

These observations show that on the 30th and 31st, when stormy weather prevailed in Upper India, but had not extended to Behar and

Bengal, the maximum temperature was considerably below the normal in Upper India (the deficiency being most marked at the hill stations), and was much above the average in Bengal, Behar, and the greater part of the North-Western Provinces. In the hill districts the maximum temperature was lowest on the last day of the storm and rapidly increased during the next few days, so that at Simla on the 5th, when the snow was nearly all melted except in sheltered spots, the maximum was slightly above the average. The most important fact is that the lowest day temperatures in the plains were not recorded during the passage of the cloudy weather of the storm, but on the first two days of cloudless skies and fine dry weather which followed the storm. The greatest depression of day temperature occurred at Lahore and Roorkee on the 2nd, at Lucknow on the 3rd, at Burdwan and Calcutta on the 4th and 5th. This transmission of the cold wave corresponds to the rate of transmission of the storm itself, which roughly averaged from 250 to 300 miles per diem, or 10 to 12 miles an hour.

The two following tables give similar data for minimum temperature. (The data are of the night preceding 8 A. M. of the day named.)

Station.	Minimum temperature of night preceding 8 A. M. of						
	Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree ...	26·7°	23·7°	25 7°	25·7°	34·7°	36 7°	34·7°
Simla. ...	24·0°	21·0°	26·2°	26·0°	31·4°	38·5°	38·5°
Lahore ...	42·1°	39·6°	42·1°	37·2°	36·2°	38·7°	41·6°
Roorkee ...	43·1°	41·1°	44·1°	41·5°	42·0°	43·1°	50·3°
Lucknow ...	56·9°	48·0°	47·0°	50·5°	46·0°	42·0°	44·0°
Patna ...	59·8°	52·9°	47·9°	49·9°	48·9°	43·8°	48·9°
Burdwan ...	62·4°	61·4°	53·3°	51·3°	43·2°	43·2°	51·3°
Calcutta ...	61·8°	61·3°	52·3°	52 3°	58·8°	53·3°	49·8°

Station.	Variation of minimum temperature of date from the normal.						
	Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree ...	−6·5°	−9·0°	−6·8°	−6·4°	+2·6°	+4·1°	+1·6°
Simla ...	−9·7	−13·1°	−8·2°	−8·8°	−3·8°	+2·9°	+3·1°
Lahore ...	−0·2	−3·2°	−1·0°	−5·5°	−6·4°	−4·0°	−0·8°
Roorkee ...	−0·3°	−2·9°	−0·7°	−3·7°	−3·6°	−2·6°	+4·7°
Lucknow ...	+10·8°	+1·8°	+0·4°	−3·5°	−1 2°	−5·4°	−3·6°
Patna ...	+10 3°	+3·9°	−1·1°	+0·5°	−0·8°	−5·9°	−1·0°
Burdwan ...	+7·7°	+6·8°	−1·1°	−3·4°	−11·7°	−12·0°	−4·1°
Calcutta ...	+6·2°	+5·8°	−3·2°	−3·6°	+2·3°	−3·7	−7 6°

These figures shew that the minimum temperature was greatly below the normal at the hill stations during the storm and largely above it in the plains on the 30th and in Bengal on the 30th and 31st, the excess being greatest in the North-Western Provinces. The night temperature slowly and steadily rose at the hill station frem the 31st to the 5th, when it was above the normal. It was lowest in the Punjab on the 2nd and 3rd, in the N.-W. Provinces on the 3rd and 4th, and in Behar on the 4th and 5th, and in Bengal on the 5th. These facts are most easily summarized by the statement that a wave of cold was transmitted eastwards across Northern India at the rate of about 300 to 400 miles per diem.

The humidity data of the same stations for the same period are even more interesting and instructive. The first of the two following tables gives the humidity at 8 A. M. and the second the aqueous vapour pressure at the stations named. The third table gives the amount of cloud at the same hour and illustrates the rapid and complete clearing of the skies which follows the cold weather storms of Northern India.

Station.	Humidity at 8 A. M.						
	Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree ...	98	100	99	83	84	26	35
Simla ...	28	31	13	47	42	58	27
Lahore ...	93	90	94	94	92	78	68
Roorkee ...	94	79	86	90	94	90	90
Lucknow ...	85	95	78	62	81	63	100
Patna ...	91	99	90	85	83	51	89
Burdwan ...	83	84	82	62	73	59	67
Calcutta ...	87	89	94	69	69	55	72

Station.	Vapour tension at 8 A. M.						
	Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree ...	·162	·159	·146	·139	·149	·069	·099
Simla ...	·049	·043	·017	·087	·067	·148	·072
Lahore ...	·335	·281	·276	·276	·245	·197	·219
Roorkee ...	·391	·261	·242	·281	·265	·259	·270
Lucknow ...	·486	·488	·316	·257	·322	·228	·300
Patna ...	·275	·525	·403	·308	·354	·237	·378
Burdwan ...	·505	·524	·480	·289	·354	·302	·299
Calcutta ...	·552	·642	·549	·357	·342	·309	·343

Station.		Cloud proportion at 8 A. M.						
		Jany. 30th.	Jany. 31st.	Feby. 1st.	Feby. 2nd.	Feby. 3rd.	Feby. 4th.	Feby. 5th.
Murree	...	10	10	10	4	0	10	8
Simla	...	10	1	2	9	0	0	0
Lahore	...	10	0	0	10	0	0	0
Roorkee	...	10	0	3	2	0	0	0
Lucknow	...	7	8	0	0	3	0	0
Patna	...	10	10	0	0	9	0	0
Burdwan	...	5	8	0	0	0	0	0
Calcutta	...	0	0	0	0	0	7	0

The second table shews that the amount of aqueous vapour pressure in the air was greatest in the Punjab on the 30th and in the Gangetic plain on the 31st. A large decrease occurred on the 1st in the Punjab, on the 2nd in the Gangetic plain, and the decrease continued until the end of the period in Bengal. The lowest aqueous vapour pressure was registered in the North-Western Provinces on the 4th and in Bengal on the 5th, and the amount of vapour was only from one-half to one-third of that present in the air on the 31st. This very great change accompanied the extension of west and north-west winds across the Gangetic Valley into Bengal.

Two more remarkable illustrations might be given from the meteorology of recent years of the remarkable weather changes which occur in the rear of cold weather storms in Northern India and follow their disappearance (*viz.*, the periods February 1st to 6th, 1886 and February 5th to 12th, 1887). The last week of January or first week of February is, in at least two years out of three, one of stormy weather in the hill districts, and some of the most severe snow-storms of recent years have occurred during that fortnight. The second of these two periods, *viz.*, February 5th to 12th, 1887 is selected in further illustration of the peculiar features of the fine weather immediately succeeding severe stormy weather in Northern India and the Himalayan region.

The disturbance which gave this stormy weather first appeared as a depression in the South-west Punjab on the 27th of January. It intensified on the 28th and moved eastwards. It passed into the Himalayan region of the North-Western Provinces on the 29th and 30th. Heavy snow fell in the North-West Himalayas and Afghan highlands at this time, and extended eastwards to the Eastern or Assam Himalayas. Stormy and cloudy weather with much snow continued over the whole Upper Himalayan region until the 7th, when the weather suddenly cleared up, and fine bright clear and cool weather prevailed for some days over the whole of Northern India.

The following tables give data of the temperature, humidity, and other meteorological conditions of the period.

Maximum temperature.

Station.	February 1887.						
	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Murree ...	37·6°	43·3°	40·8°	44·9°	41·0°	42·7°	40·5°
Rawalpindi ...	60·1°	69·2°	61·3°	63·5°	60·1°	64·1°	64·1°
Lahore ...	66·5°	67·0°	66·5°	68·5°	69·5°	68·0°	71·1°
Agra ...	73·9°	71·1°	70·1°	70·1°	72·4°	77·2°	79·7°
Allahabad ...	79·8°	73·8°	70·3°	68·8°	70·9°	74·0°	78 7°
Patna ...	77·8°	75·8°	71·7°	69·2°	70·6°	72·3°	76·3°
Calcutta ...	82·1°	82·5°	78·0°	72·5°	72·5°	72·8°	76·5°
Dacca ...	82·1°	82·7°	81·1°	77·6°	77·0°	74·4°	75·9°

Minimum temperature.

Station.	February 1887.						
	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Murree ...	25·5°	27·1°	28·6°	30·7°	29·3°	32·4°	29·7°
Rawalpindi ...	29·4°	32·9°	28·7°	33·4°	45·0°	42·0°	39·4°
Lahore ...	32·2°	31·7°	31·2°	34·2°	41·5°	46·0°	40·6°
Agra ...	46·6°	38·7°	36·7°	31·7°	41·6°	48·6°	49·2°
Allahabad ...	44·7°	41·6°	39·1°	39·6°	39·6°	41·7°	52·5°
Patna ...	50 9°	47·9°	44 7°	45·4°	43 8°	46·9°	53·4°
Calcutta ...	68·7°	59·3°	57·3°	52 8°	47·7°	47·7°	51·8°
Dacca ...	59·5°	55·2°	53·3°	49·1°	46·6°	45·5°	50·0°

Diurnal range of Temperature.

Station.	February 1887.						
	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Murree ...	12·1°	15·2°	12·2°	14·2°	11·7°	10·3°	10·8°
Rawalpindi ...	30·7°	36·3°	32·6°	30·1°	12·1°	22·1°	24·7°
Lahore ...	34·3°	35·3°	35·3°	34·3°	28·0°	22·0°	30·5°
Agra ...	27·0°	32·4°	32·3°	29·8°	30·8°	28·6°	30·5°
Allahabad ...	33·1°	31·8°	31·2°	29·2°	31·3°	32·3°	26·2°
Patna ...	26·9°	27·9°	29·8°	23·8°	26·8°	25·4°	22·9°
Calcutta ...	13·4°	23·2°	20·7°	24·8°	24·8°	25·1°	24·7°
Dacca ...	22·6°	27·5°	29·8°	28·5°	30·4°	28·9°	25·9°

Humidity at 10 hours.

Station.	February 1887.						
	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Murree ...	82	55	50	61	79	80	57
Rawalpindi ...	37	30	44	61	48	55	47
Lahore ...	33	33	24	28	28	41	34
Agra ...	33	32	28	29	25	36	39
Allahabad ...	44	38	27	31	32	24	35
Patna ...	45	54	41	38	42	43	47
Calcutta ...	85	33	32	26	34	36	53
Dacca ...	90	33	28	22	46	42	53

Aqueous vapour pressure at 10 hours.

Station.	February 1887.						
	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Murree ...	·168	·109	·126	·154	·169	·196	·148
Rawalpindi ...	·146	·116	·163	·173	·226	·211	·230
Lahore ...	·140	·135	·105	·146	·169	·235	·209
Agra ...	·183	·155	·142	·150	·145	·237	·259
Allahabad ...	·238	·158	·136	·174	·189	·174	·252
Patna ...	·308	·296	·225	·214	·238	·277	·332
Calcutta ...	·680	·261	·208	·168	·208	·237	·377
Dacca ...	·648	·289	·217	·134	·292	·295	·396

Station.	Amount of wind during 24 hours ending 4 P. M. February, 1887.						
	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Murree ...	167	117	170	117	267	206	200
Rawalpindi ...	115	155	79	56	68	58	117
Lahore ...	50	66	75	56	42	35	95
Agra ...	92	36	85	121	59	65	77
Allahabad ...	85	43	114	108	47	97	144
Patna ...	43	62	88	98	50	66	76
Calcutta ...	94	85	126	125	80	125	77
Dacca ...	34	63	99	126	62	67	40

The following gives a brief summary of the chief conclusions from the data of this period :—

1*st.*—The lowest day temperatures were recorded at Murree and the hill stations just before the storm disappeared and at the plain stations during the fine clear weather which followed the storm. The lowest maximum temperatures were observed in the Punjab on the 9th and in East Bengal on the 12th. This may be summed up by assuming the eastward passage of a cold wave along the plains of Northern India.

2nd.—The lowest night temperatures of the period were registered in the hills on the 6th and 7th during the storm, and in the plains during the fine clear weather which followed in the rear of the storm. Thus the lowest minimum temperatures occurred in the Punjab on the 9th, in the North-Western Provinces on the 9th and 10th, in Behar on the 10th and 11th and in Bengal on the 11th and 12th. This further proves the passage of a wave of cold eastwards along the length of the plains of Northern India, at a rate of about 300 miles per diem.

3rd.—The period immediately following the breaking up of the storm was one of large diurnal range of temperature. The effect of the dry weather which followed in increasing the daily range was shewn most strikingly in Bengal. The daily range at Calcutta increased from 13·4° on the 7th to 25·1° on the 12th and at Dacca from 22·6° on the 7th to 30·4° on the 11th.

4th.—There was a large temporary increase in the air motion, which was first shewn at the western stations and extended eastwards. It occurred at the Bengal stations two or three days later than in the Punjab and Western districts of the North-Western Provinces. These winds were the cool westerly winds which followed in the rear of the storm and accompanied the setting in of fine clear dry weather.

5th.—The most important change was in the amount of vapour and the humidity of the atmosphere. This was far more marked in Bengal than in the Gangetic area. In Bengal local damp sea winds prevailed during the existence of the cold weather storm, and after it disappeared they were replaced by dry land westerly winds. The humidity at Calcutta decreased from 85 to 33 and at Dacca from 90 to 33 in 24 hours. The aqueous vapour pressure data shew that this was due to a large reduction in the amount of vapour pressure and hence to the displacement of the previous winds by an air current of opposite characteristics. The amount of vapour in the air at Calcutta on the 10th was less than a fourth of that present in it on the 7th.

The following hence gives the chief features of the anti-cyclonic weather immediately following a cold weather storm during which heavy general snow has fallen in the Afghan highlands and the Himalayas:—

(*a.*)—Pressure is excessive in Upper India and unusually clear bright fine weather prevails. Strong westerly winds set in over Upper India and extend rapidly eastwards. In Bengal these winds displace the light southerly or easterly winds which prevailed during the previous disturbed weather.

(*b*)—During the stormy weather both day and night temperatures are very low at the hill stations, but, with the melting of the snow, temperature rapidly increases and the ordinary anti-cyclonic conditions of increased temperature are again exhibited at these stations. The important factor in determining this change of temperature conditions appears to be the melting of the snow from all the lower elevations.

(*c.*)—During the disturbed weather the day temperature in Upper India is below the normal and the night temperature is above it. In Bengal and Behar, in consequence of the prevalence of light southerly and easterly winds, both day and night temperatures are considerably above the normal and the weather sultry and oppressive. The disappearance of the disturbance is usually followed by a rapid reduction of both the day and night temperatures. This accompanies a complete shift of wind from some southerly to some northerly direction and the prevalence of unusually clear bright skies in which the solar radiation is even greater than usual. This passage of a wave of cold is hence evidently due to the intrusion of a body of cold air advancing from Upper India or the Himalayan mountain region into the Gangetic plain and Bengal.

(*d.*)—The setting in of these winds produces a very rapid reduction in the humidity of the air and the amount of vapour. The reduction is far greater in Bengal than in the interior, and is sometimes excessive.

(*e.*)—In consequence of these large changes of humidity and temperature, the periods immediately following cold weather storms in Upper India are especially cool, pleasant, and bracing in Bengal and stand in marked contrast to the weather prevailing before and during the existence of the storms.

We proceed to give an explanation of these facts.

The chief feature of the cold weather in Upper India is great stillness of the air, the stillness being most marked at night.

The following table gives the amount of winds measured by the self registering anemographs during the month of January 1889, and illustrates this feature of the air motion.

The following table gives the amount of wind during the day and night hours

Date.	Roorkee. Amount of wind in miles.		Lucknow. Amount of wind in miles.	
	6 A.M.—6 P.M.	6 P.M.—6 A.M.	6 A.M.—6 P.M.	6 P.M.—6 A.M.
1st January 1889.	32	3	60	24
2nd	1	0	31	24
3rd	33	0	15	12
4th	20	0	13	11
5th	2	2	12	6
6th	12	2	43	39
7th	30	10	49	28
8th	14	6	53	24
9th	14	7	30	2
10th	55	13	4	2
11th	20	0	5	1
12th	1	17	17	16
13th	44	0	41	5
14th	2	0	3	6
15th	0	2	13	9
16th	2	2	45	17
17th	5	4	33	13
18th	4	10	41	42
19th	39	18	100	47
20th	29	3	103	48
21st	4	0	26	17
22nd	18	21	40	11
23rd	29	0	14	15
24th	13	4	6	2
25th	19	0	23	6
26th	6	2	4	0
27th	6	4	4	3
28th	1	34	10	8
29th	57	153	102	100
30th	63	25	155	25
31st	26	1	57	11
Average of period from 1st to 27th.	17 miles.	4·5 miles.	31 miles.	16 miles.

These figures shew very clearly the quiescent state of the atmosphere in Northern India during the cold weather and more especially at night. This is especially observable in the periods of ordinary anti-cyclonic conditions.

In fine clear weather the range of temperature is large. It averages 27° for the whole of the Punjab for the month, and in fine clear weather usually varies little from 36°F. or 20°C. The range at the hill stations is much less, averaging 15° and rarely exceeding 18°, even in clear weather. It is not necessary to give data for these statements, as a reference to the Tables I to IV will confirm them. We shall therefore assume these two figures, *viz.*, 18° and 36°, as representing approximately the daily ranges of temperature of the air at the hill stations and adjacent plains in Upper India in ordinary fine clear anti-cyclonic weather in January. If there were absolutety no motion of the air, vertical or horizontal, an increase of temperature of 36° of the lowest strata of air over the plains would cause pressure, as measured by the barometer, to increase about two inches. No such increase actually occurs. The only large barometric movement in such weather is the diurnal oscillation (slightly exceeding in amount a tenth of an inch), which goes on with great regularity. Again, as no such large increase of pressure occurs, it is evident that it is counterbalanced by the subsequent changes of pressure due to air motion of expansion, convection currents and horizontal movement. The cooling of the air takes place most rapidly for some hours after sunset when the air movement is apparently least. The adjustment of pressure to the changing temperature conditions during night is frequently not accompanied by any perceptible or measurable air movement (*vide* data of Table, p. 41). The slightest observation of the way in which the smoke of the evening fires in an Indian town in Upper India lies over it motionless indicates clearly that the only important air movement which occurs in the evening during the rapid cooling of the air, can only be one of compression due to descent of the air above the lowest stratum, and that this is so extremely slow a process as to be imperceptible even by its action on mist and smoke. Considering the first 1000 feet thickness of the atmosphere to be homogeneous, the upper surface would have to descend about 60 feet in order to produce the compression required to maintain pressure at the same amount. This motion may appear to be considerable, but if it occurs as an accompaniment to the cooling it will take several hours to be completed. A total downward movement of the air at a height of 1000 feet through sixty or seventy feet spread over several hours is exceedingly small and cannot be detected by any of the ordinary methods of measuring air motion. The assumption of this slow motion of compression is hence in accordance with facts and competent to explain them. The cooling by night hence takes place in a nearly quiescent atmosphere, and if there be any convection currents, they are so feeble, more especially when compared with those which accompany heating during the day, as to be of no importance and negligible. Hence the motion of the air at night in Upper India during fine clear weather in January may be assumed to be a very small general downward movement producing the amount of compression necessary to counterbalance almost exactly the effect of diminishing temperature on the pressure. In the open Gangetic plain, more especially near the hills, it may be accompanied by slight horizontal movements, but they are generally too small to be measured by an anemometer. Hence the adjustment of pressure takes place in the cold weather during the day time chiefly by convection currents and partly by expansional movement of the lower strata and partly by horizontal motion from west to east or from the area of later to earlier solar action during the day; and during the night, almost solely by vertical movement accompanying or producing compression.

Through such a nearly motionless atmosphere the heat radiated from the earth's surface will pass readily. The chief proportion of the small absorption which occurs will be in the lowest strata. Hence the upper strata which receive little heat and give out little by radiation will have their temperature very slightly affected by this cause. Also if the compression of the lower strata be effected by the expansion of the upper strata, these strata will be slightly cooled, whilst the compression of the lower strata will cause a slight increase of temperature, but these changes can be shown to be so small as not to affect the temperature at the utmost more than 1° or 2°. The most important action, however, occurs in the lowest strata. The earth is cooled rapidly by radiation from its surface into space, and in the vast level plains of Northern India, the air remains quiescent or stagnant over it and hence cools down rapidly. (The cooling of the lowest strata probably takes place chiefly by conduction and to some extent by convection currents extending to a comparatively small height, determined partly by height of vegetation, trees, houses, &c.) The chief fact, however, remains that the cooling occurs in a stagnant or quiescent stratum near the earth's surface, and hence goes on continuously during the night, and produces a very large accumulated decrease of temperature.

This action is, however, chiefly confined to the lowest strata and above these the fall of temperature will be almost solely due to conduction (a slow process in air) and hence be small in amount. Also, as the lower strata are compressed and the upper strata expand, there will be some level at which at each instant there is neither compression nor expansion. Whether this will alter much in position during the night can only be conjectured, but it appears on the whole most probable that it will not. The total fall of temperature during the night will hence decrease rapidly in amount with elevation and at some elevation become practically constant where it will be due almost entirely to slight cooling by radiation and by expansion and to a very slight extent by conduction and probably not exceed 2° or 3° in amount.

In the preceding discussion it has been shewn that the temperature conditions and changes at the hill stations are usually different from those of the plain stations. For example, ordinary anti-cyclonic weather gives increased day and night temperature at the hill stations, and hence increases the mean temperature and only affects the diurnal range very slightly, whilst in the plains it gives increased day and decreased night temperature, and hence increases very largely the diurnal range of temperature, whilst it only slightly affects the mean daily temperature. Again stormy weather in the mountain districts of Northern India gives decreased day and night temperature and hence a much lower mean temperature than usual with little change in the diurnal range of temperature. The same weather in the plains gives decreased day and increased night temperature, and hence the diurnal range of temperature is largely diminished, whilst the mean temperature is very slightly affected. Hence the important conclusions,

1*st.*—That the chief weather changes and conditions in Northern India during the cold weather affect the temperature in entirely different ways in the plains and hills. In the former they modify the diurnal range of temperature chiefly and in the latter the daily mean temperature.

2*nd.*—That the monthly means of temperature or of daily range of temperature are in consequence not comparable for the hills and plain stations, and that similar variations from the normal imply different conditions and actions in the two cases.

3*rd.*—Hence the nature and causes of these changes and variations of the vertical temperature relations cannot be properly estimated and investigated by comparing monthly means, but by comparison of the actual temperature conditions prevailing in each particular state or type of weather.

Hence typical cases have been selected in the previous portion of the paper and the same principle is adopted throughout.

We are now in a position to give a simple explanation of the high night temperatures at the hill stations observed during fine clear weather in December and January.

In ordinary anti-cyclonic weather in January in the Punjab plains the temperature ranges from an average maximum of 72° to an average minimum of 36°, giving thus a mean diurnal range at such periods of 36°. The hill stations in Upper India are at an elevation of about 7000 feet above the sea or 6000 feet higher than the neighbouring plain stations. The rapid increase of temperature in the plains during the morning gives rise almost entirely to convection currents. As the air is very dry, it may be assumed that in rising and expanding it will cool and diminish in temperature at a rate not much less than that of a rapidly ascending current of dry air, which is very approximately 1° for every 193 feet. Assuming the rate of decrease of temperature in these ascending currents to be 1° for every 200 feet, the motion of the atmosphere would tend to give a temperature of (72°—30° or) 42° at the elevation of 6000 feet above the plains of the Punjab. Little or no change would occur at night, when there are practically no convection currents, and hence at that elevation above the plains of Northern India the temperature in such periods would remain permanently at about 42° and hence be about 6° higher than the average night or minimum temperature at the level of the plains below.

The day temperature at the hill stations would be considerably higher than 42° in consequence of the heating of the air by contact with the land surface, and average about 60° in such weather. About sunset temperature would fall quickly and a short period of rapid decrease of temperature would occur until the temperature reached that of the same level above the plains, *viz.*, 42°. The continuous decrease of temperature in the hills and plains for some time after sunset would evidently give rise to a compressive movement over the hills and plains and also to a very slow downward movement of air from the hills towards the plains and to a nearly horizontal upper movement from above the plains towards the hills. Hence the air which cools by contact with the mountain sides and moves down towards the plains is replaced from a large source (that of the whole mass above the plains at the higher levels), and hence arrives at a nearly constant temperature corresponding to that level. Thus air brought in from the level of 7000 feet would arrive during the night at that level in the hills at a nearly constant temperature at 42°, and hence when the temperature at the hill stations has fallen to a little below 42° it would remain fairly steady during the night at about that temperature.* As the tempera-

* In order to verify this statement I had two series of temperature observations taken in a suitable open position on the top of a ridge at Simla on the nights of the 9th and 11th of December last, when ordinary anticyclonic weather prevailed in Northern India. They are given in the following table and it will be seen fully to confirm the conclusion given in the text.

Date.	Temperature of the air.													Min. temp. during night.
	16 hrs	16·30 hrs.	17 hrs.	17·30 hrs.	18 hrs.	18·30 hrs.	19 hrs.	19·30 hrs.	20 hrs.	20·30 hrs.	21 hrs.	21·30 hrs.	22 hrs.	
December 9th	54·9	52·4	49·2	47·7	45·4	46·6	46·9	46·6	46·7	44·9	43·2	45·6	45·9	41·0
„ 11th	50·7	48·5	43·9	43·8	42·0	42·2	42·7	43·1	42·6	43·3	43·6	44·9	45·2	41·2

ture at the level of the plains would probably fall to about 36° on such clear nights, the minimum temperature in the plains would hence be slightly below that at the hill stations 6000 feet above.

The previous supposition gives an average case, and shews that in ordinary anti-cyclonic weather in December and January the minimum temperature at the hill stations tends to be higher than at the plain stations.

The following are specific examples taken from the observations of the inversion of the vertical temperature relations was most marked:—

On the 2nd the maximum temperature at Rawalpindi was 70·5°. The corresponding temperature of convection at the level of Murree 4800 feet higher would be (70·5—24°) or 46·5°. The minimum temperature on the night of the 2nd was 49·3° or slightly greater. On the 3rd, the maximum at Rawalpindi was 68·9° and the convection temperature at the level of Murree 44·9°, which was practically identical with the actual minimum at Murree 44.6°. The minimum temperatures on these two nights at Rawalpindi were 37·4° and 36 9° or 11·9° and 7·7° lower than at Murree. Again at Ludhiana on the 3rd the maximum was 77·7 and at the level of Simla 6200 feet high the corresponding convective temperature would be (77·7°—31°) or 46·7°. The minimum at Simla on the night of the 3rd was 48·4° and 2·8° higher than at Ludhiana. At Roorkee on the same day the maximum was 72·3° and the corresponding convective temperature at the level of Musoorree (6000 feet higher) was 42·3°. The minimum at Mussooree was actually 42·0° and 5·7° higher than at Roorkee. It is not necessary to multiply examples, as these shew roughly that the minimum temperatures at the hill stations and therefore the temperature *during the greater part of the evening and night* is practically that of dry air at the level of the hill station rising rapidly with the maximum day temperature at the level of the plains or what may be termed the convective temperatures corresponding to the maximum temperature conditions of the lowest stratum.

Hence the explanation and facts appear to establish the following:—

(*a*)—In ordinary anti-cyclonic weather when the horizontal air motion by day or night is very small, the temperature at

With these figures may be compared the following temperature observations recorded at Lahore on the same days.

Date.	Temperature of the air at					Maximum temperature during day.	Minimum temperature during night.
	4 hrs.	8 hrs.	10 hrs.	16 hrs.	22 hrs.		
December 9th ...	40·5	47·5	66·0	76·2	50·0	74·2	38·9
,, 11th ...	41·0	46·0	66·0	72·5	48·6	75·2	39·4

considerable elevations above the plains is nearly constant, and is determined by the temperature at that elevation of the rapid upward convective currents at the hottest period of the day.

(*b*)—There is at such periods a slow steady descent of air during the night from the hills towards the plains and a horizontal inflow from higher levels of air at nearly constant temperature to the hills.

(*c*)—Temperature decreases very rapidly at the hill stations shortly before and for some little time after sunset until the temperature falls to or slightly below that of the same level in the open atmosphere over the plains of Northern India, after which it remains nearly constant throughout the night. The short chilly period immediately after sunset is a very characteristic feature of the hill stations in ordinary fine weather during November, December, and January.

(*d*.)—The temperature of the earth's surface in the plains of Northern India falls rapidly and steadily during the whole night and until very shortly before sunrise. Hence also the temperature of the quiescent mass of air immediately above it falls *pari passu*, and by amounts ranging from 30° to 40° in ordinary clear weather in January. The fall of temperature is greatest at a considerable distance from the foot of the hills, where the observations shew that the maximum temperatures are higher, the daily range of temperature greater, and the minimum frequently lower than immediately under the hills. The following gives examples for the 2nd and 3rd January, 1889. The stations which were to be compared are grouped by means of brackets.

Station.	2nd			3rd		
	Max.	Min.	Range.	Max.	Min.	Range.
Ludhiana ... ... }	69·7	41·0	28·7	75·2	45·6	29·6
Lahore ... ... }	72·0	36·2	35·8	73·0	37·2	35·8
Roorkee ... ... }	70·8	38·9	31·9	70·8	36·6	34·2
Meerut ... ... }	72·7	42·1	30·6	74·2	39·0	35·2
Delhi ... ... }	73·1	41·1	32·0	78·1	40·1	38·0
Bareilly ... ... }	73·7	41·3	32·4	71·2	39·8	31·4
Agra ... ... }	75·6	44·6	31·0	78·6	43·6	35·0
Gorakhpur ... .. }	68·9	45·4	23·5	71·8	47·9	23·9
Lucknow ... ... }	75·2	43·0	32·2	71·1	41·1	30·0
Allahabad ... .. }	71·4	43·7	27·7	77·0	42·7	34·3

As there is little or no difference, so far as can be judged, in the radiating power of the earth's surface at Ludhiana, Roorkee, Bareilly, and Gorakhpur as compared with Lahore, Delhi, Agra, and Allahabad in January to account for the greater cooling of the earth's surface and the superincumbent air, it is almost certain that the mass of air descending from the hills is warmed by the action of compression in descending, and that this is one, if not the chief, factor in giving a smaller fall of temperature and slightly increased night temperature at the stations nearest to the hills when compared with the more distant ones. Hence it is clear that the descending air does not contribute towards the cooling of the plains of Northern India during the night but actually tends to diminish it.

The efficient factors in the rapid cooling of the air in the plains of Northern India at such periods are :—

1*st*.—Absence of cloud and other conditions favouring rapid radiation from the earth's surface.

2*nd*.—Absence of air motion, and more especially of downward convection currents, so that the same mass of air remains in contact with the earth's surface.

The first ensures the rapid cooling of the earth's surface and the second of the air immediately above the earth's surface.

A brief explanation will serve for the temperature conditions in Upper India during and after stormy weather. The most important factor appears to be snow fall in the hills and rain in the plain districts. The condensation takes place largely, if not almost entirely, in the upper return current of the north-east monsoon circulation and hence at a great elevation. The falling rain and snow carry down with them the temperature of their place of origin and hence tend to cool considerably the whole mass of air through which they fall. The amount of the cooling will evidently depend greatly upon the amount and period of the rain and snowfall. In the hill districts, the temperature falls steadily throughout a long snow storm, and the lowest temperatures are usually recorded just before the weather begins to clear. In the plains, the day temperature falls in consequence of cloud and rainfall and the action of rainfall referred to above. But the cloud canopy causes terrestrial radiation to proceed very slowly at night. The effect of the cloud in diminishing radiation is so large that the night temperatures are hence at such periods considerably higher than usual. Hence stormy weather in January and February depresses temperature largely throughout the whole day at the hill stations, and in fact tends to give them a temperature nearly equal to the permanent temperatures of a stratum considerably above their level (*i. e.* of the stratum in which condensation occurs). Whereas in the plains the chief effect is to diminish the daily range of temperature by decreasing the day and increasing the night temperature.

Finally, when the stormy weather passes away unusually dry clear weather sets in. In the hills the snow probably extends down to a level of 4,000 or 5,000 feet. The temperature of the air at and above that level is mainly determined by that of the snow surface with which it is in contact, and hence, even in the middle of the day, differs little from 32°. Hence a period of low and nearly constant temperature conditions sets in until the snow is melted and the snow line retreats. The snow melts very rapidly, at a rate of six to nine inches *per diem* in clear weather in exposed positions, and a snow fall of 3 or 4 feet will melt away and disappear in five or six days in favourable weather except in sheltered positions. Consequently, temperature in the hills at such periods is at first low, but rapidly rises with the melting of the snow, and after a few days of fine clear weather the conditions merge into those of normal ordinary anticyclonic weather, which have been already stated.

In the plains the conditions and actions are different. Solar radiation during such periods is more active than usual in consequence of the great clearness of the atmosphere, the absence of dust, &c. Hence not only is the upward convective motion over the plains during the day greater than usual, but in consequence of the low temperature over the snow-covered surface of the hills there is a rapid flow of air from the hills towards the plains, which in consequence of the first action is probably greater by day than by night. This mass of air starting from, say, a level of 4000 feet above the plains at a temperature of 32° will by rapid descent be heated about 20° and hence will arrive at the level of the plains at a temperature of about $32° + 20° = 52°$, or 20° lower than the maximum temperature prevailing in the plains in ordinary anticyclonic weather. Hence there will be a steady flow of cool air towards the plains from the hills, the temperature of which, when it arrives at the level of the plains, will be very low when compared with the ordinary day temperature at the period. As the snow melts and the snow line ascends, the temperature of the descending current at the level of the plains will increase. Hence in the plains immediately after a severe storm in the hills there will be,

1*st.* A strong and steady current from the hills towards the plains and hence a strong easterly current from the north northwest and west down the Gangetic Plain.

2*nd.* This current will be fed from a source of nearly constant temperature above the elevation of the snowline, and hence the temperature of the descending current at the base of the hills will be least immediately after the clearing up of the weather, and will increase slowly with the melting of the snow in the hills. Hence one of the most striking features is the low maximum temperatures recorded at such periods in Upper or Northern India, although the air is unusually clear, and the solar radiation at the earth's surface more intense than usual.

3rd. One of the chief features of a descending current is great dryness, hence the descending currents from the hills at such times will tend to give abnormally low humidity to the whole area over which their influence extends. The change of humidity due to this will evidently be greatest in the area over which damp sea winds previously prevailed, that is, usually in Bengal.

It will thus be seen that the features of the very cool and dry periods after stormy weather in Northern India during January and February are explicable on the assumption of unusually large and massive currents from the hills at a time when the snow surface has greatly extended downwards.

It is hardly necessary to point out that these cool periods are of occasional occurrence in Bengal, and are the most characteristic and pleasant feature of the cold weather. These cool periods in Northern India hence shew most strikingly the rapid and large influence which snowfall over a large mountain area exerts. Mr. Blanford and myself have shewn the probably large influence it occasionally exercises on the distribution of the south-west monsoon rainfall. This has been questioned by some writers as the effect appears to them to be disproportionate to the cause. The large changes in air motion, temperature, and humidity over the whole of Northern India which follow general snowfall in the hills, and which continue for longer or shorter periods according to the intensity and extent of the storm, are a frequent strong argument in its favour.